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CONTENTS

A Review of the Vegetable Oil Position.....by W. Poggendorff 1

The Effect of Cobalt Sulphate on the Cobalt Content of Subterranean Clover (*Trifolium subterraneum* L. var. *Dwalganup*) at Three Stages of Growth.....by R. C. Rossiter, D. H. Curnow and E. J. Underwood 9

A Relationship between Soils and Topography in South Western Australia.....by Robert Smith 15

Transmission of Bunchy Top to Banana Varieties.....by C. J. Magee 18

The Use of Benzene Hexachloride in North Queensland Canefields.....by J. H. Buzacott 24

Molybdenum and Other Fertilizers in Pasture Development on the Southern Tablelands of New South Wales.....by A. J. Anderson 28

The Need for Destructive Criticism.....by G. W. Leeper 33

Technical Notes—

The Coefficient of Variation of Wool Fibre Fineness with Age and Fleece Site.....by W. R. Lang 36

Lime in Relation to Clover Nodulation at Sites on the Southern Tablelands of New South Wales.....by A. J. Anderson and D. Spencer 39

The Australian Institute of Agriculture—

Meetings of Council and Branches..... 42

Current Notes and News..... 44

Book Reviews..... 45

Personal Notes..... 46

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VOL. 14, No. 1 MARCH, 1948

A Review of the Vegetable Oil Position*

By

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Vegetable oils and fats play a very versatile part in meeting our needs in the form of food, lubricants, paints and varnishes, drugs, fuel, linoleum, printer's ink, cosmetics, soap, pharmaceuticals, and hydraulic transmission agents. In some of these uses, vegetable oils are interchangeable with fats and oils of animal or mineral origin ; in others they are practically irreplaceable. Most of us have probably experienced the effects of the war-time shortage of paint and linoleum, which still persist because linseed has always been imported, mainly from India, which has suffered from successive droughts and famine.

Because of our wealth in animal fats, and for climatic reasons, Australia is not a great consumer of edible oils, but these are very important ; for instance, in Britain, in the form of margarine, which is cheaper and practically equivalent nutritionally to butter. Some idea of the importance of the edible oils to Britain can be found from the recently commenced project involving three million acres proposed for peanuts in East Africa, and the present visit of a British Food Mission here. One of the objectives of this Mission is to investigate the possibility of greatly increased edible oil production in Australia. Incidentally, both the huge East African scheme, and the Mission's visit here, are a pertinent comment upon the probability of future supplies of oils from India, the former chief source of supply. Britain is also devoting land which can ill be spared from food production to growing linseed.

Will you, and particularly the chemists among you, please forgive a brief revision of the elementary chemistry of the vegetable oils, since it will be necessary to refer to some chemical characteristics in dealing with individual examples.

Chemistry of the Vegetable Oils.

Vegetable oils are of two kinds :

(1) Fixed, or non-volatile—mainly in seeds and fruits.

(2) Volatile or essential—mainly in leaves, stems and flowers.

The principal function of the fixed oils in plants seems to be that of a food supply for the seedling during its development. Apart from the attraction that flower perfumes have for bees, the function of the essential oils is not obvious.

Chemically, all fixed oils and fats are compounds of a particular alcohol, glycerine, with fatty acids. The vegetable waxes and some of the essential oils are also fatty acid esters, but with alcohols other than glycerine. The glycerine molecule is trihydric and capable of combining with three molecules of a fatty acid to form glycerides ; rather strangely, the natural glycerides are almost invariably of mixed

* Presidential address to the N.S.W. Branch of the Institute, February, 1948.

constitution, each glycerine molecule combined with three different fatty acids. Oils and fats consisting of only one glyceride are very rare ; they are usually more or less definite mixtures of two or more glycerides.

There are seven principal series of fatty acids, of which five are important in the commoner vegetable oils and fats :

(1) *Stearic*—all saturated—single carbon linkages throughout.
(2) *Oleic*—all containing one double link in the molecule.
(3) *Linoleic*—all containing two double links in the molecule.
(4) *Linolenic*—containing probably three double linkings.
(5) *Clupanodonic*—probably has four double links, and is characteristic of fish oils.
(6) *Hydroxylated*—one or more OH groups present.
(7) *Cyclic*—characteristic of chaulmoogra and *Hydnocarpus* oils used in treatment of leprosy.

The relative proportions of the triglycerides of these fatty acids determine the properties of a particular fat or oil, and lead to an important practical classification.

(*a*) Drying—e.g. linseed, important in paints and varnishes.
(*b*) Semi-drying—Sunflower, soybean, intermediate in character.
(*c*) Non-drying—olive, coconut.

The obvious method of determining the classification of a given sample of oil would be to determine its oxygen-absorbing power, and the type of film, if any, that it produces on oxidation. Unfortunately no satisfactory means of performing this test quantitatively has yet been found, but the Wijs-Hübl iodine value supplies a very close approximation of the drying power of an oil. Briefly, it consists in treatment of the oil with a solution of iodine monochloride, ICl, under standardized conditions, when one of each pair of double or triple-linked C atoms attaches an iodine atom and the other a chlorine atom, giving a saturated chlor-iodo compound. Obviously, the best drying oils, rich in unsaturated glycerides, would be expected to have the highest iodine values, whilst the relatively saturated non-drying oils would be much lower on the scale, although this is not strictly true.

Many other tests are used in identification of fats and oils, and determination of their suitability for particular purposes, for instance specific gravity, solidifying point, refractive index, viscosity, solubility, saponification value, bromide value, acid value, and many specific tests.

Interchangeability and Processing of Oils.

To a certain extent, some oils are interchangeable for specific purposes. Thus tung oil could be used to replace linseed, and peanut oil could substitute olive, but oils in their natural state can be modified by physical and chemical means to adapt them better for other uses. Amongst the most important of these processes are :

(1) *Hydrogenation*—causes a progressive and preferential saturation, commencing with the most unsaturated group, reducing it to the next, and so on back to the fully saturated stearic group.
(2) *Dehydration*—removal of OH group from hydroxylated acids, increasing the iodine value.
(3) *Molecular fractionation*—separation of a semi-drying oil into two parts by making use of differential solubilities of the fractions in furfural or propane.

Vegetable Oil Consumption in Australia.

Any attempt to establish detailed statistics concerning imports, production and avenues of consumption of fats and oils in Australia is fraught with the most extraordinary difficulties. Whilst in charge of oil crops during the war, I attempted it repeatedly without success. Believing that things might be somewhat easier now, I passed the task on to colleagues in the Division of Marketing to whom, and particu-

larly to Mr. Gruen, I am indebted for most of the statistics used tonight. But they still complain of the same difficulty in collecting reliable and detailed information.

Table 1 shows the average annual consumption of various oils in Australia, and the principal uses to which they were put, in so far as they can be ascertained.

TABLE 1.

Estimates (in tons) of Vegetable Oil Consumption in Australia Before and During World War II, based upon Average Annual Consumption of Various Products.

	Total.		Soap.		Margarine.		Paints.		Linoleum.	
	Pre-War Average.	War Average.	Pre-War Average.	War Average.	Pre-War Average.	War Average.	Pre-War Average.	War Average.	Pre-War Average.	War Average.
Tung oil	1,033	260					900*	242		
Linseed oil	12,423	12,630					4,888	6,398	1,260	1,255
Cottonseed oil ..	1,204	700*	22	10	598	352				
Rapeseed oil	634	949								
Peanut oil	1,664	2,536			708	1,691				
Olive oil	1,523	392	535†	1,135†						
Coconut oil	12,463	14,611	5,979	5,952	6,072	8,395				
Other oil seeds ..	1,718	1,730								
	32,664	32,172	6,536	7,079	7,378	10,438	5,788	6,630	1,260	1,255

* Rough estimate only.
† Palm and olive oils.

Oil Investigations in Australia.

(1) DRYING OILS.

Linseed. This is easily the most important drying oil used in the paint and varnish industry; Australia consumed approximately 12½ thousand tons annually pre-war, entirely imported as linseed, mainly from India. The press-cake is a valuable stock food.

Many attempts which have been made to grow linseed commercially in New South Wales have failed, generally due to disease and insect pests, and the relatively low prices of the imported Indian and Argentine linseeds. In 1935, however, a new trial was commenced with two varieties on which a very successful linseed industry had been built in California under irrigation. These varieties, Punjab and Abyssinian, showed immediate promise when sown at Leeton Experiment Farm, on the Murrumbidgee Irrigation Area. After three years' trial, seed distribution had commenced when rust, *Melampsora lini*, appeared in epidemic form, and has been present practically every season since. Fortunately an intensive introduction programme had secured several promising rust resistant varieties in the meantime, and the best of these, Walsh, is the basis of the present attempt to establish Australian self-sufficiency in linseed, pending further testing of very promising hybrid material.

Stirred by an existing linseed shortage, the Commonwealth Government guaranteed New South Wales growers £34 per ton for Walsh linseed in 1944-45. Thirty-two tons of seed were stored by the N.S.W. Department of Agriculture during 1945-46, when no guarantee was offered, and very few crops sown. Meggitt Ltd. originated a scheme to purchase this seed from the Commonwealth, who insisted, however, that it be divided between that firm and Harold Meggitt Ltd. Both firms have let contracts to selected farmers, guaranteeing £40 per ton or world parity c.i.f. ports, which ever is the higher on delivery. Some 1950 acres were sown, mainly in New South Wales, but also in Victoria, Queensland and Tasmania, to distribute the risk of failure. Growing conditions have been very favourable, but some crops were damaged by rain. Yields of up to 19 bushels per acre are reported.

A notable record was established—for the first time in Australia, airplanes were used commercially, thanks to the enterprise of East-West Airlines, for dusting crops with D.D.T. Complete control of the *Heliothis* moth pest was obtained.

The total crop, when finally harvested and cleaned, is estimated to yield 480 tons, sufficient to sow nearly 40,000 acres during the 1948-49 season. Based on a conservative estimate of 10 bushels per acre, this should yield a total of 10,000 tons in 1949-50. This is still short of normal requirements, but providing a substantial contribution to crushing, after deducting the 1,250 tons of seed required to sow the 100,000 acres estimated to be necessary to supply all immediate annual requirements.

Tung. Tung oil, long a valued Chinese export of unknown origin, is expressed from the nuts of *Aleurites* spp., chiefly *A. Fordii* (Euphorbiaceæ), a tree to which the North Coast of New South Wales is extraordinarily well suited. Planting in this State commenced in 1926 ; 922 acres were recorded for New South Wales in 1941-42, but only 100 acres in 1947. From personal experience, I may say that statistics for tung are most unreliable, but oil production figures are accurate as they emanate from one firm only.

Tung oil has some very unusual properties, including the highest known specific gravity and refractive index of all oils, conferred largely by a high proportion of the otherwise rare elæomargaric acid, a stereo-isomeride of linolic acid. Tung production has not flourished as it could on the North Coast for many reasons, but the potential value of the industry is so great that strenuous efforts to reorganize it on sound economic lines would be well worth while. The chief defects of this potential industry in the past have been :

(1) The indiscriminate planting of unselected stock.
(2) High cost of transport of small individual consignments of nuts to Sydney.
(3) Shortage of labour for gathering nuts.
(4) Uneconomic returns due to inefficiency in production and marketing, and the fact that there is no buying competition. The one firm on the market does not offer growers very attractive terms.

To remedy this state of affairs, high-yielding strains are now available, the most suitable districts and locations can be well defined, and a mechanical picking-up machine is in course of development. An attempt was made to have a minimum price determined for the nuts, without success. The Australian demand for tung oil has never been satisfied, and there is a vast world market awaiting the development of this industry.

Perilla. Perilla oil is obtained from the seeds of two species—*P. ocymoides* and *P. Nankinensis* (Labiatæ), native to East Asia. The oil has an extraordinarily high iodine value, but, very curiously, does not dry as readily as linseed. The plant, which has been tried at Grafton and Wellington, is an annual of indeterminate flowering habit. Like sesame, it commences to flower when quite small and continues indefinitely. The flowers are succeeded by seed pods ; the basal seed pods promptly dehisce when ripe, though the top of the plant may still be flowering. Economic mechanical harvesting is consequently almost impossible.

Candlenut. This oil is obtained from a relative of Tung—*Aleurites moluccana*, the candlenut, widely distributed throughout the East Indies, Pacific Is. and northern Queensland. It is a reasonably good substitute for linseed, but is more troublesome to extract because of the hard shell, and the meal, like Tung, is poisonous to stock. Very large quantities are available, but collection is tedious, and disorganized at present, and shipping facilities for such a relatively bulky material are very limited.

Hempseed. This oil is mentioned chiefly as a matter of interest, because of the great range of iodine values it displays, probably as a result of growing almost anywhere from the tropics to temperate climates. Its cultivation is prohibited in Australia because, although it also produces a valuable fibre, the plant is the source of the drug variously known as marijuana, bhang, hashish.

(2) Semi-drying Oils.

The line of distinction between drying and semi-drying oils is difficult to define, and varies according to different authorities. Somewhat arbitrarily, it may be taken as an iodine value of 150.

Safflower. Safflower, *Carthamus tinctorius* (Compositæ), is a hardy annual, suited to wheat districts, and more adaptable in its requirements than linseed. Its yield per acre is about the same as wheat, and it is even more productive under irrigation. Its seed has a hard shell, necessitating decortication before oil extraction. Local tests have given oil yields of 17 to 28 per cent. according to variety and growing conditions, with an iodine value of 140 to 149. Safflower oil can be considered only an extender of linseed oil, but the crop could be grown where linseed could not. Commercial development is taking place in South Australia, where 10 tons of seed have been introduced, unfortunately too late for planting last autumn.

Saffron Thistle. This plant, *Carthamus lanatus*, is closely related to safflower, and is very widely distributed. Large quantities of its seed are harvested involuntarily in most seasons, with the wheat crop in which it occurs. In a good season many thousands of acres carry a dense crop of saffron thistle. Typical analyses show about 18 per cent. of oil similar to safflower oil in physical characteristics. A small tonnage of seed is being harvested at present, with which to conduct oil tests on a small commercial scale.

Soybean. Soybeans contain about 18 per cent. of oil with an iodine value of 126 to 135. It is a true semi-drying oil with a complete fatty acid group range from stearic to linolenic. In its natural state it is widely used overseas as an edible oil, and to some extent as a drying oil extender, but its fatty acid constitution, and the recent development of a molecular fractionation process render possible the splitting of it into two fractions with enhanced drying and non-drying properties respectively.

Many attempts have been made to establish the crop, which is of undoubted value in many respects, in Australia. A current major attempt appears to be losing way, at least in New South Wales, on adverse seasonal and economic grounds. Approximately 1000 acres were sown to soybeans in this State last season, chiefly on the Northern Tablelands. This season's recorded acreage is about 200, half on the Coast. Last season's crop still remains unsold (February, 1948) at the price of 35*s.* per bushel demanded by growers.*

An intensive introduction, variety testing and selection programme over the past 30 years has failed to reveal a variety which will yield consistently under our erratic climatic conditions. A South African selection, Potchefstroom 169, appears to be the best yet found.

Sunflower. Sunflower seed contains an oil with an iodine value 120 to 136. Sunflowers are grown for oil production on a vast scale in Russia and South America, and could be produced readily here with existing equipment. Trade objections to the crop as a source of oil in normal times are that the oil is inferior in drying power to linseed, that the seed requires decortication before pressing if a good oil yield is to be obtained, and that the press cake is unknown to a stock food market accustomed to linseed and copra cakes. A fair average yield is half a ton of seed per acre. Some of the newer dwarf varieties under trial and seed increase are not only much easier to harvest with a wheat header, but also more uniform in maturity, and better yielders than the old tall varieties. This crop offers by far the greatest promise of rapid development for edible oil production, at least in New South Wales.

Maize. Maize contains about 12 per cent. of an oil with an iodine value of 115 to 125. The germs, separated during the process of starch manufacture, yield about 40 per cent. of oil. Increased production of maize for oil alone is obviously impracticable.

Cottonseed. Cottonseed contains about 20 per cent. of oil with an iodine value of 105-112. The press-cake is a valuable stock food. Cotton production has been confined to Queensland, where it is decreasing in spite of subsidies. Mechanical picking which has been achieved in America, together with defoliation of the plants with a cyanamid compound, may open the way to increased Australian production.

*Since sold (March, 1948) at nearly 32s. per bushel.

Very successful experimental crops have been grown in New South Wales, at Emmaville, Wellington, Hay and Yanco.

Sesame—Sesamum indicum (Pedaliaceæ). Sesame is an important food and source of edible oil in most tropical countries. A once extensive export trade from India has suffered from competition by palm, copra and peanut oils. Some 60 varieties have been tried at Grafton and Leeton Experiment Farms. Good yields have been obtained from some varieties, but harvesting is a problem because of shattering. A search for non-shattering varieties has been unsuccessful to date. Sesame oil has an iodine value of 103 to 110.

(3) Non-drying Oils.

Rapeseed. Rapeseed oil, also called colza, is produced in large quantities in the temperate regions of Europe, Asia and America. This oil has peculiar characteristics which fit it pre-eminently as a marine engine lubricant—high viscosity and non-gumming. The iodine value is 100, which may be taken, arbitrarily again, as a convenient separating mark between the semi-drying and the non-drying oils.

Mustard produces a similar oil, but is very pungent due to the presence of essential oil of mustard. Both rape and mustard have been produced very successfully in New South Wales, yields of more than half a ton of seed per acre being obtained. Aphids have been a limiting factor in production, but are now readily controllable with D.D.T.

Wild Rape, Turnip, Mustard. Several Cruciferous plants commonly occur as weeds in wheat crops and, like Saffron Thistle, are harvested involuntarily. In good seasons, dense natural stands of wild mustard occur which should readily repay harvesting. The fixed oil approximates rapeseed oil in characteristics.

Peanuts. Peanuts yield a valuable edible oil rich in the oleic group of fatty acids. The practical absence of the more unsaturated or hydroxylated groups renders it quite unfit for use as a paint oil, or even as an extender, but it ranks next to olive oil for edible purposes. The crop requires a long warm growing season, an ample and well-distributed summer rainfall, and a relatively dry autumn. These climatic conditions are found mainly in Queensland and the Northern Territory. Production on the north coast of New South Wales has been small and erratic. Australian production is centred around Kingaroy, Queensland, where 58,000 acres have been planted this season, an increase of 50 per cent. over the recent average. A vast British market for peanuts is opening up, and a great increase in the Queensland area sown to peanuts is possible on the basis of long-term contracts which would stabilize increased production.

Castor. Castor oil is obtained from the seeds of *Ricinus communis* (Euphorbiaceæ) to the extent of 46 to 52 per cent. The oil is characterized by the presence of a very high proportion of ricinoleic acid, an hydroxylated acid which confers high specific gravity, and viscosity. The plant thrives in many parts of New South Wales, often occurring in dense natural stands, the exploitation of which was commenced by a local firm this season. Castor can be cultivated readily, but usually, tall growth and shattering of the seed spike render it quite unamenable to economic harvesting. Some dwarf, non-shattering varieties have, however, been introduced and together with some local selections, are under trial both at various experiment farms, and with farmers under contract to the firm mentioned.

Castor oil is an extraordinarily versatile material. Apart from its well-known but quite minor medicinal use, it is an almost ideal motor lubricant, having high viscosity and being insoluble in petrol. It has numerous industrial applications, amongst the latest being as a source of sebacic acid and capryl alcohol—important plastic raw materials. In its natural state, it is almost perfectly non-drying, being used for instance to keep fly-paper and tree-banding preparations viscid. By chemical dehydration, a partial polymerization occurs with formation of lactones,

and the oil resembles tung in its properties, the iodine value having been increased from about 88 to approximately 160.

Castor became an emergency war-time crop in America. If the experiments at present in progress here can solve the various inherent difficulties, we should acquire a valuable new farm crop. Incidentally, the castor plant is the fastest known producer of cellulose, is the source of an insecticide, and of a fat-splitting enzyme.

The family Euphorbiaceæ, of which Castor and Tung are members, commends itself to the seeker of extraordinary oils. Another member is *Croton*, which yields a violently purgative oil rich in valeric acid, and still another is *Sapium sebiforum*, the Chinese Tallow Tree, which provides a vegetable fat.

Olive. Although olive trees will flourish in many parts of Australia, the chief deterrents to increased production are the high cost of labour to collect the fruit, and the time taken for the tree to commence profitable cropping. South Australia is the chief local source of olive oil, but recent reports indicate large plantings in Victoria.

Coconut. Copra, the source of coconut oil, is produced chiefly in tropical Pacific islands. Many plantations were ruined during the war, and labour and shipping difficulties are hindering rehabilitation of the industry, which is likely to require years to return to normal.

The Present Position.

A survey of the various vegetable oils thus briefly reviewed shows that coconut and linseed are of outstanding importance in their respective spheres.

It became very evident during the war that Australia's complete dependence upon outside sources for both these oils could have very serious results in the event of interruption of supplies. The probability that future supplies of linseed from India, and of other oil seeds from abroad will decrease, and the uncertain future of copra supplies, render imperative the development in Australia of supplies of these oils or substitutes for them.

The present attempt to produce our entire requirement of linseed by 1950-51 has been mentioned, as have also various other possible local sources of drying oils. Copra production in certain tropical parts of Australia does not appear to be economically feasible, but fortunately it is possible to substitute animal fats to a large extent, and several other vegetable sources of edible oils could be readily developed, particularly sunflowers and peanuts. In spite of the present attempt to foster soybean production, I am not very hopeful concerning the economic establishment of this crop, and since 1943 have been urging the development of sunflowers.

In 1946, a Commonwealth Mission of Investigation visited America to inquire into the soybean industry in U.S.A., and the possibility of establishing it in Australia, but the report presented on their return embraced a very much wider field. The Mission recognized that Australia was dependent upon overseas supplies of drying oils and recommended local production, also the economic production of soybeans, sunflowers and peanuts, pointing out that although the principal use of these oils overseas is for human food, nevertheless they can be used as partial substitutes for drying oils. Within the limits already mentioned in the cases of soybean and sunflower oils, but excluding peanut oil as a drying oil substitute, the recommendation is praiseworthy.

It was further recommended that " the upper limitation of the quantity of oil that could be converted into foodstuffs for human consumption would be controlled by existing State legislation, so that the dairy industry would not be challenged ". This can be challenged on two grounds—firstly the possibility of an export market opening up, and secondly the economics of butter production. I propose to return briefly to the second of these presently. A third reason advanced by the Mission for encouraging oil-crop production is the quantity of protein-rich concentrates which would be furnished by the oil meals. The fact is that in normal pre-war times

very large quantities of oil-cakes were burnt under boilers because no immediate market was offering and storage was uneconomic. The future economic use of large quantities of oil-cake will depend upon the widespread adoption of better methods of stock feeding so persistently advocated by stock authorities, and upon the rationalization, on a national basis if necessary, of oil-cake utilization and long-period storage against recurring droughts.

A desperate world-wide shortage of fats and oils exists and is likely to continue for at least three to five years. One of the objectives of the present visit of the British Food Mission is to encourage vastly increased production of vegetable oils in Australia. The Mission is particularly interested in supplies of peanuts, sunflowers and linseed. Soybeans would be welcome, but not at the price at present demanded by growers. Long-term contracts are being offered which would encourage the development of stable oil crop production.

It is obvious that an extraordinary opportunity exists for Australia to develop new industries or expand older ones to help both Britain and herself. The obvious bottleneck at present is the acute shortage of agricultural machinery, labour and materials, but the Mission is also investigating, on behalf of the British Overseas Food Corporation, the possibility of taking up land, introducing labour and machinery, and undertaking production.

Foremost among the fats used for human consumption in Australia is, of course, butter. In spite of the fact that a given area of fertile land can produce approximately four times as much edible fat in the form of oil crops as can be produced by dairy cows, and at approximately one-quarter the cost, pound for pound, butter is so firmly entrenched in popular favour that even food-desperate Britain continues to produce and import butter, admittedly as a luxury. Australia can afford the luxury of butter far more readily than Britain, but it is significant that restrictive legislation is necessary to prevent strong competition by margarine even in Australia. There will continue to be a steady increase in the economic pressure of butter substitutes derived from vegetable oils, these are much cheaper and nutritionally almost equivalent to butter. In the words of an eminent dairy authority, Mr. A. H. Ward, Director of Herd Improvement and Statistician of the New Zealand Dairy Board, dairying, and particularly the butter industry, has but five years as a maximum limit in which to increase its efficiency on a major scale. I venture to suggest that this will entail not only a great increase in average production per cow, but also a far more efficient and economic use of skim milk than feeding it to pigs. The present state of affairs, under which the removal of cream from milk also removes nine-tenths of its original value, is obviously ridiculous.

The Commonwealth Government has accepted a recommendation by the Agricultural Council that a Vegetable Oils Committee be set up to recommend broad policy on vegetable oil production to the Agricultural Council.

Conclusion.

It seems obvious that Australia must make a determined effort, not only to become potentially self-sufficient in the production of both drying and non-drying oils (or do without to a greater or lesser extent), but also to develop a huge export market in oil seeds to Britain on liberal terms.

At the present stage of experience, the crops considered most capable of development are :

(1) As sources of drying oils : Linseed, Tung, Castor, Safflower.

(2) As edible oil crops : Sunflower, peanuts.

(Received for publication, 10th March, 1948.)

The Effect of Cobalt Sulphate on the Cobalt Content of Subterranean Clover (Trifolium Subterraneum L. var. Dwalganup) at Three Stages of Growth

By
R. C. Rossiter,* D. H. Curnow† and E. J. Underwood.‡

During the spring months of 1944, it was observed that sheep grazing on a pasture consisting of Dwalganup subterranean clover and perennial veldt grass (*Ehrharta calycina* Sm.) at the Institute of Agriculture, University of W.A., Perth, were rapidly losing condition despite the abundance of available feed. It was suggested that the animals might be suffering from cobalt deficiency. This opinion was supported by *post-mortem* examination of one of the animals and analysis of the liver for cobalt.

The soil is a light grey podsolized siliceous sand, slightly acid in reaction (pH=6·1). The discovery of cobalt deficiency was not unexpected in view of the probable origin of this soil type. Crocker[4] has postulated a scheme in which siliceous sands, similar in type to the above, are derived from "æolianite", in the coastal areas of southern Australia, while the geochemical evidence of Thomas[10] suggests that cobalt deficiency might be expected on such soils.

A full account of the work on cobalt deficiency carried out in various countries up to 1943, with a complete bibliography, was published by Russel.[9] The results of New Zealand work on the effect of cobalt applications to pastures have been summarized by Askew.[1] Examination of the literature cited by these authors indicated that critical data on the effect of stage of growth of the plant on cobalt content were extremely meagre. Almost all the experimental work was conducted without adequate statistical control, so that the significance of the factors affecting variation in cobalt status of pastures could not properly be assessed.

It is the purpose of this paper to present results of an investigation on the effects of varying rates of cobalt application on the cobalt content of Dwalganup subterranean clover at three defined growth stages, to measure the residual effects in the following year, and finally to discuss the findings in relation to published data.

Experimental Procedure.

The experimental site had been sown to a mixture of Dwalganup subterranean clover and Wimmera rye-grass (*Lolium rigidum* Gaud.) in 1940. No defined grazing plan had been imposed in the ensuing years, and in order to ensure a clover-dominant pasture in 1945, the area was cultivated twice early in the season (on May 10th and May 21st). The final germination occurred on May 27th, and was almost exclusively of subterranean clover seedlings.

Nine treatments were included: three levels of cobalt application, together with the three growth stages. These may be shown schematically:

Co_0 S_r
Co_1 × S_f
Co_2 S_m

Co_0=no cobalt.
Co_1=4 oz./acre $CoSO_4.7H_2O$.
Co_2=8 oz./acre $CoSO_4.7H_2O$.

S_r =rosette stage.
S_f =maximum flowering stage.
S_m=maturity.

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On June 8th, the area was pegged to provide 45 plots, each 12×12 links. On the following day basal dressings of superphosphate and muriate of potash were applied at the rates of 3 cwt./acre and 1 cwt./acre respectively.

The nine treatments were freely randomized within each of five blocks, since the two main effects were required with approximately equal precision.

The cobalt salt was applied, in solution, on June 16th, 1945. No applications were made in 1946.

At each sampling date an area of 25 sq. links was harvested from each plot,* the material rapidly sorted to remove any extraneous species, then washed to remove traces of soil and finally oven-dried at 90° C. for 24 hours.

Yield figures were determined at the rosette and flowering stages only; it was not possible to sample accurately at maturity, owing to the chance of soil contamination. Representative sub-samples were taken from each sample and stored in Co-free stoppered bottles for cobalt determination. Thus cobalt was determined on each of the five replicates of each of the nine treatments.

Sampling dates for the two years were as follows:

	1945	1946
Rosette stage	August 14th.	June 17th.
Flowering stage	September 18th.	August 22nd.
Maturity	November 8th.	November 6th.

Delay in the rosette and flowering stages in 1945 was the result of the late establishment in the first year of the trial. Germination occurred on May 27th in 1945 (*vide supra*) and on April 23rd in 1946.

Chemical Method. The method of analysis of the pastures was based on the procedure of Beck[3] with a modification suggested by Marston (private communication) to decrease extraction of iron with the cobalt. After wet digestion the calcium sulphate was filtered off, citrate added and the solution brought to pH 5·5. Nitroso naphthol was added and the solution heated to ensure formation of the cobalt complex. Any iron complex formed was decomposed with sulphuric acid and the cobalt complex extracted with chloroform. The complex is destroyed by digestion with nitric, sulphuric and perchloric acids and the cobalt estimated by a method which is essentially that of Marston and Dewey.[6]

Results.

Effect of Cobalt on Yield of Dry Matter.

The yields obtained over the two seasons 1945 and 1946 are shown in Table 1.

TABLE 1.

Mean Yield of Dwalganup Subterranean Clover (Cwt./Acre D.M.), 1945 and 1946 Figures Averaged.

Growth Stage.	Amount of $CoSO_4.7H_2O$ Applied.			Mean.
	Nil.	4 oz./acre.	8 oz./acre.	
Rosette	5·31	5·80	5·71	5·61 } S.E.±
Flowering	14·17	14·92	14·45	14·52 } 0·660
Mean	9·74	10·36	10·08	10·07

S.E.±0·809.

* At the final sampling in the second year (November, 1946) the plots were badly infested with capeweed (*Cryptostemma calendulaceum* (L.) R.Br.). A small sample only of clover was collected from each plot and the replicates bulked for chemical analysis.

As expected, there was no significant effect of cobalt on pasture yield at either the rosette or flowering stage, and no interaction with growth stage.

The highly significant increase in production from the rosette to the flowering stage provides some indication of the growth rate during this period.

In 1946 the yields were nearly 50 per cent. higher than in 1945; the figures are not presented in detail, since there was no significant interaction between years and cobalt treatment.

Effect of Cobalt on Relative Amount of Cobalt in the Plant.

1945 Data: A summary of the cobalt analyses of samples collected in 1945 is given in Table 2. The figures for the untreated plots are well below the generally accepted critical level of 0·07 p.p.m. D.M. for sheep (Russel[9]), at all growth stages.

TABLE 2.

The Effect of Cobalt on the Relative Amount (p.p.m. D.M.) of Cobalt in Dwalganup Subterranean Clover at Different Growth Stages, 1945.

Growth Stage.	Amount of $CoSO_4.7H_2O$ Applied:		
	Nil.	4 oz./acre.	8 oz./acre.	Mean.
Rosette	0·04 (0·616)	0·23 (1·356)	0·51 (1·710)	0·17 (1·227)
Flowering	0·04 (0·572)	0·17 (1·218)	0·41 (1·616)	0·14 (1·135)
Maturity	0·04 (0·652)	0·18 (1·262)	0·27 (1·438)	0·13 (1·117)
Mean	0·04 (0·613)	0·19 (1·279)	0·39 (1·588)	0·14 (1·160)

Note.—In Tables 2 and 3 figures in brackets are means of logarithms into which the original data × 100 were converted for the purposes of statistical analysis. The other figures in the table are geometric means (antilogarithms ÷ 100).

Differences required for significance:

Means of 15 at 1 per cent.	(0·111)
„ „ „ „ 5 „ „	(0·083)
„ „ 5 „ 1 „ „	(0·165)
„ „ „ „ 5 „ „	(0·123)

Consideration of the main effects, viz. rate of cobalt applied and growth stage, shows that the former has by far the dominant effect. The mean values for the three cobalt levels, after averaging for growth stage, are clearly related to the amount of cobalt applied to the pasture, and the mean differences are each highly significant (1 per cent. level).

A highly significant interaction was found between growth stage and rate of cobalt applied. While no decrease in cobalt content occurred with increasing plant development on the control plots, there was a pronounced and significant decrease at maturity where 8 oz./acre of the cobalt salt was applied. No such significant decrease at maturity was found with the 4 oz./acre rate and the difference between the rosette and flowering stage, though marked, was significant at the 5 per cent. level only.

1946 Data: The residual effects of the cobalt treatments were measured in 1946, samples being taken from areas immediately adjacent to those of the previous year. A summary of the figures obtained is shown in Table 3.

As in 1945, the major effects resulted from the differential cobalt dressings. These were still very obvious, though less pronounced than in the first year, and the differences between treatment means were highly significant (1 per cent. level).

TABLE 3.

The Effect of Cobalt on the Relative Amount (p.p.m. D.M.) of Cobalt in Dwalganup Subterranean Clover. Residual Effects, 1946.

Growth State.	Amount of $CoSO_4.7H_2O$ Applied in 1945.		
	Nil.	4 oz./acre.	8 oz./acre.
Rosette	0·04 (0·596)	0·09 (0·938)	0·14 (1·148)
Flowering..	0·05 (0·676)	0·09 (0·962)	0·15 (1·164)
Maturity	0·04	0·11	0·17

Differences required for significance :

Means of 10 at 1 per cent. .. .. (0·083)

,, ,, ,, ,, 5 ,, ,, ... (0·058)

Note.—Values for the maturity growth stage determined from bulk samples of replicates.

The only significant effects arose from the cobalt dressings applied in the previous year ; there was no significant difference between the rosette and flowering stages. Taking into consideration the values obtained at maturity, it is clear that any real interaction effect is extremely doubtful.

Effect of Cobalt on Absolute Amount of Cobalt in the Plant.

From the dry matter yields at the full flowering stage, it was possible to calculate the absolute quantity of cobalt in the tops at this time. The values so obtained represent with reasonable precision the total uptake of the mineral for any one season.

TABLE 4.

The Absolute Amount of Cobalt Present in the Tops of Dwalganup Subterranean Clover, in Relation to Rate of Cobalt Application. (Gm. per acre.)

Cobalt Applied, 1945.	Nil.	4 oz./acre. $CoSO_4.7H_2O$ (=24 gm./acre Co).	8 oz./acre $CoSO_4.7H_2O$ (=48 gm./acre Co).
Cobalt uptake, 1945 ..	0·027	0·112	0·244
Cobalt uptake, 1946 ..	0·030	0·081	0·137

Since cobalt applied at the rates used has no effect on plant growth, relative and absolute amounts will be highly correlated. The figures presented in Table 4 are of interest in two respects :

(i) they demonstrate that uptake of cobalt was approximately proportional to the amount supplied ; and

(ii) over the two-year period the quantity of applied cobalt absorbed by the plant was less than 1 per cent.

Discussion.

Recent New Zealand work (e.g. Askew and Watson[2]) has shown that variation in cobalt content of herbage is not very marked under grazing in bush-sick areas. On the other hand the results of earlier investigations (e.g. McNaught and Paull[5]), have been interpreted to explain the severe November-February disease incidence by seasonal variation in cobalt content of the pasture. That such variation occurs in

healthy areas of New Zealand seems well established, but the evidence from affected areas is by no means beyond dispute.

Maunsell,[7] in a recent study of a bush-sick pasture, has shown that no relationship exists between cobalt content and plant growth rate. The cobalt content varied from 0·09 p.p.m. D.M. to 0·11 p.p.m. D.M. only, while growth rate of the pasture varied from 2 lb. to 67 lb. D.M. per acre per 14 days. These results are extremely significant, since they indicate that, even when plant growth rate is varied over a wide range, the concentration of Co in the plant tends to remain constant.

In Western Australia Underwood and Harvey[11] found a slight increase, from flowering to maturity, in the cobalt content of a pasture, the chief component of which was the Mt. Barker variety of subterranean clover. This increase was of doubtful significance assuming that variability was of the same order as in the present experiments. In the present experiments there were no significant changes in cobalt content of the subterranean clover from the untreated plots between the rosette and flowering growth stages and at maturity in either year, despite great differences in plant growth rates prior to sampling. It appears very probable, therefore, that in "deficiency" areas the cobalt content of the pasture remains remarkably uniform throughout the year.

In New Zealand considerable work has been carried out with the object of ascertaining the minimum cobalt dressings required by deficient pastures to render them healthy for grazing stock. Much of this work has recently been summarized by Askew,[1] who states that the best returns are obtainable by giving annual applications of 4 oz. of hydrated cobalt sulphate (or its equivalent in cobalt) per acre or 8 oz. per acre every second year. Smaller dressings, as low as 2 oz. per acre annually, gave satisfactory stock health with wether hoggets, but Askew claims that the extra value in meat and wool from the sheep on the pastures receiving 4 oz. annually or 8 oz. biennially more than compensated for the cost of the additional cobalt.

Unfortunately, it was not possible to carry out grazing trials to support the present experiments. If, however, the figure of 0·07 p.p.m. of cobalt on the dry basis be taken as the minimum "healthy" level for grazing sheep, it is apparent from Tables 2 and 3 that a single dressing of 8 oz. cobalt sulphate per acre was more than sufficient for the production of "healthy" pasture for two seasons and a single dressing of 4 oz. per acre was just sufficient for this purpose for the same period. Under these conditions it would, therefore, seem reasonable to argue that rather lower dressings than those recommended by Askew (*loc. cit.*) would be adequate. The experimental data suggest a linear relationship between amount of cobalt applied and cobalt content, and on this assumption 3 oz. hydrated cobalt sulphate per acre annually or 6 oz. biennially would give satisfactory results.

A point of some interest, and possibly practical importance, is the extremely inefficient use of the mineral applied in this way. The data in Table 4 disclose the fact that only about 1 per cent. of the added cobalt, at the levels used, was recovered in the plants over the two-year period. This low recovery is of some interest in view of the contention of Mitchell[8] that cobalt and nickel are more firmly held than the usual exchangeable bases in soils. Critical studies of the recovery of cobalt, including the use of fairly heavy and infrequent dressings, are required. There are, however, a number of practical advantages in supplying cobalt to animals by way of the pasture, in comparison with direct administration in the form of drenches or licks. It can be applied once every year or every two years as a part of the ordinary fertilizer mixture (e.g. "cobaltized" superphosphate) with no extra cost in labour or machinery. Moreover, a continuous and fairly uniform intake by *all* grazing stock is ensured.

Although the results presented above are confined to one species (*T. subterraneum* v. *Dwalganup*), a few cobalt determinations were made on other pasture species including capeweed (*Cryptostemma calendulaceum* (L.) R.Br.), Wimmera rye-grass (*Lolium rigidum* Gaud.) and perennial veldt grass (*Ehrharta calycina* Sm.). Samples

of these species were collected in August and again in December, 1945, from pastures on the Institute soil to which no cobalt had been applied. The range of values obtained extended from 0·03 to 0·06 p.p.m. on the dry basis and coincided exactly with that of the individual replicates of the untreated clover plots in the main experiment. Little published information on the cobalt content of individual pastures species in cobalt-deficient areas exists but species differences so far noted have not been substantial.

Summary.

The results of an experiment designed to measure the effects of cobalt applications on the yield and cobalt content of Dwalganup subterranean clover at three defined growth stages are reported. Sheep grazing on the area adjacent to the experimental plots had been shown to suffer from cobalt deficiency.

The cobalt treatments had no influence on yield of clover over a period of two years.

The heavier dressing of cobalt (8 oz. $CoSO_4.7H_2O$ per acre) raised the cobalt content of the clover to high levels in the year of treatment and maintained values well above the minimum level required by grazing sheep in the year following treatment.

The lighter dressing (4 oz. $CoSO_4.7H_2O$ per acre) similarly raised the cobalt content to high levels in the year of treatment, though not to the same extent as with the heavier dressing, and maintained values just above the minimum levels required by sheep in the year following treatment.

The cobalt content of the clover on the untreated plots was remarkably uniform, in each year, at the three growth stages studied (viz. rosette, flowering and maturity), in spite of marked differences in plant growth rate.

Over the two year period less than 1 per cent. of the cobalt applied was absorbed by the plant, uptake being approximately proportional to the amount supplied.

Samples of other plant species, including capeweed, Wimmera rye-grass and perennial veldt grass, taken from an area to which no cobalt was applied, were found to have a similar range of values for cobalt as the clover from the untreated plots in the main experiment.

The significance of these findings in relation to published findings is discussed and the suggestion made that adequate cobalt levels could be maintained on pastures of the type studied by the application of 3 oz. of hydrated cobalt sulphate (or its equivalent in cobalt) per acre annually or 6 oz. per acre biennially.

Acknowledgements.

We are indebted to Dr. H. W. Bennetts, of the Department of Agriculture, for the *post-mortem* examination of sheep leading to the original diagnosis of cobalt deficiency, and to Mr. R. G. Coleman, of the Institute of Agriculture, for assistance with some of the cobalt analyses.

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A Relationship Between Soils and Topography in South Western Australia

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Introduction.

During recent soil survey work at Kojonup, Western Australia, an important relationship has been established between soils and topography. This relationship, which has been observed at a number of points throughout the agricultural area of Western Australia, promises to provide an understanding of certain of the complex soil patterns which are found in this area.

The following discussion concerns the distribution of laterite in an area adjacent to the township of Kojonup, in the vicinity of a granite boss, which acts as a local drainage divide. More general observations made over a wide area of the Western Australian wheat belt confirm the conclusions arrived at from the detailed study at Kojonup. For the purposes of this note, the word " laterite " is used to describe formations composed largely of ironstone gravels, boulders or hardpan. The term " lateritic soils " refers to soils which contain laterite in the forms described. It is considered that most soil profiles described as lateritic have resulted from the re-sorting of the original Tertiary profile in which the laterite was formed, and further that the mechanism of " soil creep " has been a potent factor in this re-sorting of the unconsolidated soil materials on the slopes of the granite boss at Kojonup.

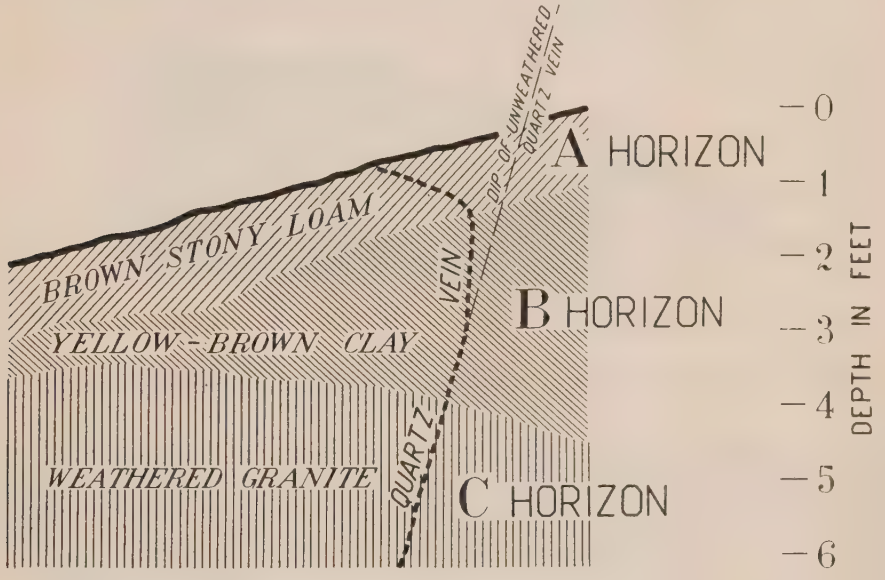

Figure 1.
Illustrating the process of " soil creep " on steep slopes.

Soil Creep as a Factor in Soil Formation.

" Soil creep " is a term used to describe the slow movement downhill of soils situated on slopes. Under the influence of gravity a loosely coherent body such as soil assumes some of the properties of a liquid. The movement induced in the soil

is akin to the " flow " of ice down a glacier and is governed by more or less the same laws. Where resistance is lowest, as at the surface, the displacement is greatest, whereas the drag of unweathered immovable rock in the subsoil and the resistance offered by actual rock outcrops reduces movement in these vicinities. These generalizations are illustrated graphically in Figure 1. This diagram, which refers to an actual road cutting in the Darling Range area, shows soil formation on a steep slope. The granitic country rock is weathering deeply to produce a soil in which " A " and " B " horizons are clearly discernible. A narrow quartz vein which cuts through the granite strongly resists weathering and the quartz pebbles in the soil profile act as indicators of the amount of displacement which has occurred. It can be clearly seen that movement of the " A " horizon is much greater than that of the " B " horizon. As the " A " horizon contains a much higher proportion of the coarser soil fraction than the " B " horizon, it follows that sand, gravel, and stones will tend to be removed from the site, whereas the clay fraction will be enriched. The operation of this process over a long period of time appears to offer a sufficient explanation of the mechanism by which considerable depths of kaolinitic clay accumulate on hillsides in south-western Australia.

Soil Formations on the Kojonup Granite Boss.

The broad soil and geological relationships of the Kojonup area are shown in Figure 2. This section, which extends a distance of a mile and a half from a rocky

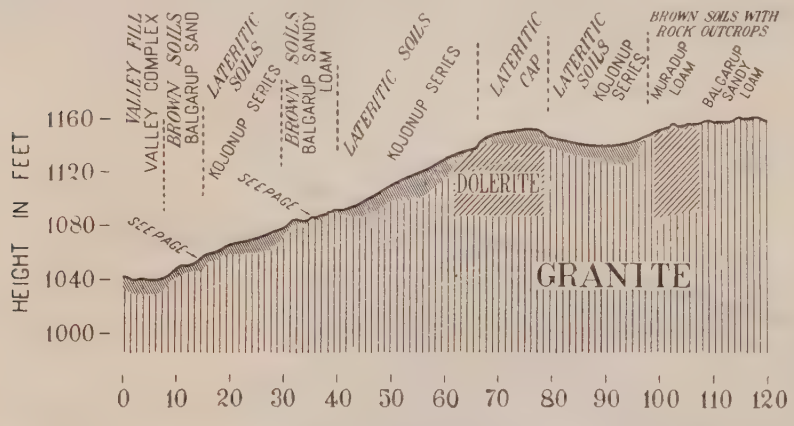

Figure 2.

Section in the Kojonup district showing broad relationships between soils and geological formations.

hilltop to a drainage line, has a total fall of 120 feet. The country rock, which consists of granite with intrusions of dolerite, is imperfectly covered by a mantle of unconsolidated material to a maximum depth of twenty feet. Where the country rock is exposed to weathering under the present climate, the soils consist of brown sandy loams and loams with reddish brown clay subsoils, overlying rock at approximately two feet. Soils of the Muradup series develop over dolerite and soils of the Balgarrup Series develop over granite. Where the country rock is buried beneath old soil formations the soil profiles consist of grey sands and sandy loams containing lateritic gravel, overlying a yellowish grey clay subsoil at about two feet. This clay is remarkable for its kaolinitic nature and for its considerable depth (up to twenty feet). These lateritic soils, which belong to the Kojonup soil series, are considered to be derived by re-sorting from an original lateritic soil formation, largely by the mechanism of soil creep.

A further soil formation is shown towards the middle of the section where a flat-topped hill rises rather steeply to the level of the top of the boss. A cap of massive laterite several feet thick has protected this area from erosion. Dolerite outcrops below the breakway and it is reasonable to assume that the laterite cap was originally formed from the weathering products of the dolerite. It can be further argued that, whereas the high iron content of the dolerite resulted in the formation of massive laterite, the granite which contains few iron-bearing minerals produced pisolitic gravels which are easily transported. On the level terrain of drainage divides is found a highly leached soil which may represent an undisturbed Tertiary soil profile. An example of this soil type is the Carrolup sand:

0-3 ft.	A	Grey to white sand.
3-5 ft.	B^1	Pisolitic and massive laterite.
5 ft.	B^2	Mottled yellow brown, red brown and grey clay.
Variable depth ..	C	Granitic country rock.

It is the down slope creep of soil materials from such formations as the Carrolup sand which ultimately produces the profiles of the Kojonup and similar soil series.

The movement of soil is paralleled by the lateral percolation of water. The crystalline rocks of the boss are almost impermeable and water tends to move down slope through the relatively permeable unconsolidated materials. Areas of the Kojonup soil series act as intake beds both for water falling as rain and for run-off from higher rocky areas. The farmer exploits this characteristic by locating his wells, soaks and excavated tanks on soils of the Kojonup series. Where the Kojonup series gives place to Balgarrup or Muradup series on a shallow rock formation the percolating ground waters are forced to the surface to form seepages, as shown on Figure 2, and the same rock bar halts the downhill creep of all but the surface sandy horizons.

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Transmission of Bunchy Top to Banana Varieties

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Nomenclature of Varieties.

On the basis of common names, most of which are of local origin, the number of banana varieties in cultivation throughout the world would appear to be very large. Until Cheesman,[1, 2] as a preliminary to breeding work against Panama disease (*Fusarium oxysporum* var. *cubense*), undertook the huge task of classifying banana varieties, chaos existed in varietal not to mention species nomenclature. Cheesman, by bringing together in Trinidad varieties from different parts of the world, has proved synonymy for numerous varieties previously known by many confusing local names.

From this study it has emerged that actually there are relatively few distinct varieties among those bananas which are cultivated commercially throughout the world. Some of these have been listed by Cheesman[2] in order of importance as commercial dessert bananas as follow: Gros Michel (type 1), Dwarf Cavendish (type 2), Giant Cavendish (type 3), Congo (type 4) and Lacatan (type 5). On a production basis, Gros Michel is outstandingly the world's most important commercial variety, although in different parts of the world one or more of the other four varieties exceeds Gros Michel in local importance. All five varieties (and other seedless varieties) are infertile or relatively infertile hybrids, being triploids in nuclear constitution as compared with the diploid and tetraploid condition of seeded *Musa* spp. Obviously it is the absence of seed in infertile *Musa* spp. which throughout the ages had led to their selection as edible bananas, and the question of the seeded species from which they have evolved is still uncertain. A botanical classification of the seedless *Musa* spp. at present would be unreliable (see Cheesman[2]).

When the five varieties mentioned are further codified, it is found that on the basis of morphology, fruit characteristics, and resistance to Panama disease, they fall into two classes, viz. the Gros Michel group, comprising the Gros Michel, and the Cavendish group, comprising the other four types. In the banana, as in many vegetatively propagated crops, mutants arise frequently. Some are selected for local propagation, so that within each of the above varieties many sub-varieties or strains must be included.

In Cheesman's studies there have been included besides the most important varieties, many that are less important and less known, but very wisely, owing to the danger of introducing bunchy top into the Caribbean region, the varieties cultivated in the numerous Pacific islands have not received attention. Of importance among these is the Veimama of the Fijian Islands. This variety possesses most of the morphological and physiological characteristics of the Cavendish group and, from comparative studies, it is the writer's opinion that this variety should find a place in a sub-section of this group.

It will be seen from the above that the present study, which was initiated with the object of selecting a commercial banana resistant to bunchy top and suitable for Australian cultural conditions, narrowed itself down to a testing of only two varietal, or perhaps specific, groups. This was only realised as the work progressed. All varieties of any consequence grown in Australia were assembled, but the somewhat difficult task of importing bananas from overseas was confined to selected varieties of agronomic and commercial promise.

Results of Inoculation.

Each variety after a preliminary quarantine, was propagated in twelve-inch pots and at the third or fourth leaf stage was inoculated by means of infective aphids (*Pentalonia nigronervosa* Coq.).[4, 7] A standard method of inoculation was adopted in which twenty nymphs, bred on a recently infected Cavendish plant, were transferred in spring-clip cages (modified Storey[6] type) to the last-emerged leaf of each plant. From two to four plants of each variety (see Table 1) were tested. This method of inoculation led to infection in every plant tested with the exception of two groups of two Gros Michel plants inoculated on different occasions. Each of the four Gros Michel plants concerned, however, was subsequently proved capable of being infected by heavy inoculation with groups of 200 aphids (all developmental stages) previously fed on recently infected Cavendish plants.

It will be seen from Table 1 that infection has been obtained in all the five types mentioned above (Trinidad type material being used in three cases) and a number of local and imported varieties of doubtful affinities. When these results are considered in conjunction with observations on the wide range of infection in important varieties in the different countries (Table 1) in which bunchy top has occurred, it would seem that the chances of obtaining an immune and commercial type are not great.

TABLE 1.

Varieties of Bananas in which Bunchy Top Disease has been Observed.

Observed by the Writer and Others.		Transmitted by the Writer to the Following Varieties.
Country.	Variety.	
Fiji	Dwarf Cavendish.	Dwarf Cavendish.
	Gros Michel.	Gros Michel.
	Veimama.	William's Hybrid (Fischer's strain).
	Raratonga.	William's Hybrid (Gaudron's strain).
	Vundi.	
	I.C.2.*	
Australia	Dwarf Cavendish.	Mons Mari.
	Gros Michel.	Mons Mari (D. Brown).
	William's Hybrid.	Soden (H. L. Anthony).
	Mons Mari.	Golden Gros Michel.
	Veimama.	Sugar.
	Samoan China.	Ladies' Finger.
	Ladies' Finger.	Veimama (ex Fiji).
	Sugar.	Samoan China (ex Tonga).
	Plantain.	Bungulan (ex Philippines).
Ceylon	Hondarawala.	Naine (ex Mauritius).
	Anamalu.	Wagup (ex Noumea).
	Suwandel.	Grand (ex Noumea).
	Alu-Kehel.	Dwarf (ex Africa).
	Kolikuttu.	Giant Chinese Type 3 (ex Trinidad).
	Surrumundang.	Congo (Fiji, ex Trinidad).
	Three unidentified varieties.	Lacatan (Fiji, ex Trinidad).
Egypt	Hindi or Dwarf Cavendish.	Puvan (ex India).
North Borneo ..	Gros Michel (?).	Rasthali (ex India).

* Observed by Parham.[5]

High Degree of Resistance of the Gros Michel Variety.

The failure to infect readily the Gros Michel plants by the standard method of inoculation adopted indicates a degree of resistance to bunchy top in this variety unlike that yet encountered in any other. The display of resistance by Gros Michel has been substantiated by field observation by the writer in Australia, Fiji and North

Borneo. Further evidence of resistance to infection by Gros Michel is available from two comparative glasshouse tests with Dwarf Cavendish and William's Hybrid (apparently a mutant of the Cavendish, of intermediate statute), adopting the standard method of inoculation referred to earlier. In the first test, five Cavendish plants contracted the disease, while none of five Gros Michel plants succumbed. In the second test with William's Hybrid the same figures were obtained.

The factors which contribute to the bunchy top resistance of Gros Michel are undetermined. They might be physiological ones, or perhaps structural, depending upon the greater stature and consequent length of the vascular channels separating the point of inoculation and the region of differentiating tissues. When Gros Michel does contract bunchy top following heavy infestation with infective aphids, its reaction to the disease is in every way as severe as that of members of the Cavendish group, although the incubation period of the disease may be ten to twenty days longer.

In spite of the partial collapse of its resistance under epidemic conditions, it is believed that Gros Michel would prove a satisfactory variety for defeating the disease under most conditions. This opinion is based on field observations in Fiji and a consideration of the part the variety played many years ago in temporarily rehabilitating the Fijian industry after it had been destroyed by bunchy top.[4] Observations made by the writer in Fiji in 1937 showed that in plantations established with the Gros Michel variety, a clone, relatively few stools had succumbed to the disease in epidemic surroundings created by close proximity of infected plantations of members of the Cavendish group.

Unfortunately, Gros Michel, because of its special requirements in relation to soil and climate, can never become a very important variety in the present infected areas in Australia. In Fiji also, the variety is of limited value owing to its liability to hurricane damage. There are prospects, however, that mutants of this variety, if they retain resistance to bunchy top, may prove useful. It is considered that in the first instance a search for and examination of such mutants would be more remunerative than effort by hybridization with these difficult plants, where only the infertile are of commercial value.

Behaviour of the Veimama Variety in Relation to Bunchy Top.

In 1935 Mr. E. P. Foster, Fruit Inspector, N.S.W. Department of Agriculture, drew the writer's attention to the unusual behaviour of some young infected Veimama plants growing in a plantation at Duranbah, N.S.W. These plants, after having formed several badly streaked leaves, had developed a number of leaves of normal appearance in which relatively few streaks could be detected. This behaviour of infected plants was so different from anything previously observed that the plants concerned were labelled and their further growth studied. The plantation in which the plants occurred had been recently planted, and a check of the source from which the suckers were supplied revealed the presence there of several infected stools which had previously escaped detection. Nevertheless, it could not be determined with certainty whether the unusual plants were cases of primary or secondary infection, and if primary, what the history of the parent stools had been.

The Veimama variety at present is the most important one in cultivation in Fiji, and from time to time reports had been received that it possessed resistance to bunchy top. Other reports, however, had denied these claims. A series of tests was therefore conducted to determine whether Veimama succumbed to inoculation less frequently than Dwarf Cavendish, the most important variety of Australia. The results of these tests are shown in Table 2. In four experiments ten nymphs (*P. nigronervosa*) which had been bred on recently infected Cavendish plants were transferred in spring-clip cages to each of the plants under test. It will be seen that nineteen of the twenty-two Dwarf Cavendish plants inoculated became infected and twenty-one of the twenty-six Veimama plants. These figures are not significantly

different. In length of incubation period of the disease and severity of symptoms both varieties behaved similarly.

Meanwhile, the Veimama plants behaving unusually at Duranbah (nine in number) were kept under observation, being sprayed weekly with nicotine and soap to obviate their proving possible sources of infection to neighbouring plants. All plants grew to maturity and produced bunches, comparable in quality and weight to those of surrounding healthy plants. In Figure 1 is shown a stool formed by one of

Figure 1.

Veimama stool partially recovered from bunchy top, showing normal maturation of the bunch.

Figure 2.

Young primary infected Veimama re-infected with bunchy top after partial recovery from the disease. Note severe symptoms in the three youngest leaves and marginal chlorosis in the one preceding them.

TABLE 2.

Relative Susceptibility to Inoculation with Ten Infective Nymphs of the Varieties Dwarf Cavendish and Veimama.

Date.	Variety.	Number of Plants Inoculated.	Number of Plants Infected.
15.1.1937	Cavendish.	10	9
	Veimama.	10	9
3.2.1937	Cavendish.	5	5
	Veimama.	5	3
26.1.1937	Cavendish.	5	4
	Veimama.	5	5
26.2.1937	Cavendish.	2	1
	Veimama.	6	4

the plants. Although the stool is of normal appearance, close inspection throughout its growth showed the presence of green streaks, characteristic of the disease, in almost every leaf thrown. These streaks, however, were represented in most leaves by only a few green dots, or at most by a streak a few centimetres long parallel with a few

only of the subsidiary veins of the laminæ. Such symptoms would quite easily have escaped notice had they not been a subject of search, but their presence indicates that complete recovery from the disease was not attained. Further, suckers propagated from such partially-recovered plants invariably showed the streak symptoms of bunchy top in the laminæ of the first three or four leaves thrown by young plants. Thereafter the plants proceeded to form leaves entirely normal in appearance, and later, the fact that the plants were infected could only be determined with the greatest difficulty. At a stage of growth shown in Figure 1, if the older leaves have withered, the closest examination may reveal no sign of the characteristic streaks and diagnosis must depend on the presence of one to several veins with transparent areas, located in the distal end of some of the laminæ.

Re-infection of Partially-Recovered Veimama Plants.

It was of interest to determine whether plants propagated by suckers from partially-recovered Veimama stools could be re-infected with bunchy top in its typical form. It was found that this could be done, but that the number of infective aphids necessary to bring about infection was greater than that required to infect Dwarf Cavendish plants of the same age. In one experiment ten young Dwarf Cavendish plants and ten partially-recovered Veimamas, of similar age, were inoculated with ten infective nymphs bred on a recently infected plant. Nine of the ten Cavendish plants later became infected, although no evidence of re-infection appeared in the Veimamas, even up till the sixth leaf thrown after inoculation.

The ten plants which had resisted infection in the experiment just described were again inoculated, using thirty infective nymphs per plant. Four of the ten partially-recovered Veimamas became infected as well as all the ten control plants used as a check on the source of inoculum. One of the reinfected plants is depicted in Figure 2, and shows the symptoms of the disease in severe form. The remaining six plants had become pot-bound by the time the experiment was terminated and were unsuitable for further inoculation. Similar results were obtained in another experiment ; five Cavendish plants inoculated with ten infective aphids contracted bunchy top, while five partially-recovered plants inoculated from the same colony, resisted re-infection.

Availability of the Virus in Recently-Infected and Partially-Recovered Veimamas.

The availability of the virus in recently-infected Veimama plants was compared with its availability in recently-infected Cavendish plants. A plant of each variety which had been inoculated on the same day and had later shown first-symptoms of the disease on the same day, was colonised with *P. nigronervosa*. One week later, groups of five nymphs from each colony were transferred in spring-clip cages to each of five young *Musa nimbin* seedlings. (This name is given to an unclassified seeded *Musa* sp. found at Nimbin, N.S.W., and widely used by the writer as a test plant and for culturing the virus and its vector.) Five of the five test plants became infected in each case. This experiment was repeated with the same results, indicating in the case of recently-infected plants an equal availability of the virus in both varieties.

Attempts made so far to obtain the virus from partially-recovered Veimama plants have been unsuccessful. Five experiments involving five individual partially-recovered plants have been conducted. In the first two experiments, recently propagated offsets which showed streaks along many of the veins of the laminæ were colonised with aphids, and two weeks later groups of ten nymphs were transferred to each of ten test plants. Negative results were obtained. In the third and fourth experiments two plants at approximately the stage of growth of the plant shown in Figure 2 were colonised with aphids, and subsequently groups of ten nymphs were transferred from the colonies to each of ten test plants for each experiment, again

with negative results. In the fifth experiment, groups of nymphal aphids were selected from a colony which had been established for more than two months on a large partially-recovered Veimama plant (approximately nine months old), growing in an experimental plot at Sydney. The aphids were selected from the last-emerged leaf and were transferred in groups of twenty to each of ten test plants. Again negative results were obtained.

The above results suggest a very low availability of the virus in partially-recovered Veimama plants.

Origin of Partially-Recovering Veimama Plants.

The question of the origin of the " recovering " characteristic of certain Veimama plants is undecided. The history of the material discovered at Duranbah suggested that they were merely primary-infected plants which had been propagated in error, and it was assumed that a similar behaviour might be expected in primary-infected suckers derived from any secondary-infected Veimama plant. Such, however, is not the case. Of twenty-five Veimama plants inoculated experimentally and later transferred to field plots at Duranbah, not one has shown signs of recovery, either in its current growth or in its ratoons. The same results have been obtained with infected plants of other varieties (all those in list of experimental inoculations in Table 1) treated in a similar manner.

" Recovering " plants of the Veimama variety have been collected from one other source as offsets from stools which have shown bunchy top in a very mild form, but the history of such stools is no better known than those which provided the Duranbah material. Suggestive evidence that the " recovering " plants are primary-infected offsets of a certain type, perhaps with a dosage of an attenuated strain of the virus, was obtained by the writer during a visit to Fiji in 1937. In Fiji no organised attempt is made to eradicate the disease, and in almost any native plantation large numbers of infected stools may be examined. In one large stool which consisted of eight to ten plants, most of which were showing severe symptoms of bunchy top, a tall sucker, healthy in appearance, was found arising from the midst of a group of dwarfed and severely-rosetted suckers. The sucker of healthy appearance showed streaks only in the two oldest leaves and appeared to the writer as being of a type identical with the Duranbah material. It was unmistakably a primary-infected sucker which had behaved very differently to its sister suckers. Examination of hundreds of other infected Veimama stools, however, revealed no other cases of apparent recovery *in situ*.

Until more data becomes available regarding the origin of " recovering " plants, speculations only can be made regarding the factors controlling the extreme localisation of the virus within the plants and their apparent acquired resistance. In the reports of the Director of Agriculture, Fiji, commencing in 1912, some fragmentary accounts are given of an experiment, or experiments, relating to the propagation of banana plants which had recovered from bunchy top. These reports were discussed at length by Gadd[3] in 1926, who considered the experiments of some importance, but enquiries and examination of official records made by the writer in Fiji in 1937 indicated that the experiments were allowed to lapse through lack of promise. The variety concerned in these recovery trials appears to have been Cavendish.

Yield Test of Partially-Recovering Veimama Plants.

The difficulty encountered in re-infecting partially-recovered Veimama plants suggests that they possess an acquired resistance to bunchy top and in view of the fact that satisfactory fruit may be grown by infected plants, this " strain " was considered worthy of examination for possible economic value. Accordingly, field plots to determine its yielding capacity in relation to Veimama and Cavendish and whether it would function as a " carrier " variety were established at Duranbah and

maintained for two years. Yields of the strain were disappointing in comparison with healthy Veimama and Cavendish. It is of interest that there was no evidence that the partially recovered strain served as a source of infection to the other varieties, among which it was interplanted during the period of the yield trial.

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The Use of Benzene Hexachloride in North Queensland Canefields

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The white grub (*Dermolepida albohirtum* Waterh.) is easily the most important insect pest in north Queensland canefields. Although the damage it causes fluctuates widely from year to year, losses are almost always in excess of £10,000 per annum. In one year it was estimated to exceed £250,000. As with most insect pests, it is sporadic in its attacks, and infestations vary in different localities and in different years. Heavily infested crops may be total losses and involving also the ratoons normally to be expected from these fields. In the past the control of this pest has been an expensive, highly skilled procedure and, even with expert attention, satisfactory results could not always be obtained.

Fumigation as a Control Measure.

Fumigation has proved the only practice of any value in the control of this white grub, but before this is done extensive diggings have to be made to locate areas of infestation. This is done before there is any above-ground evidence of the presence of the grubs, and must be carried out thoroughly. The results of such diggings have to be related to soil type, moisture, variety, etc., and long experience is needed to interpret correctly the figures obtained. Carbon disulphide, alone or in combination with paradichlorbenzene, is the standard fumigant used and is injected in small doses along the rows of cane stools. The work has to be done in the hottest time of the year, during the wet season and in cane so tall that it effectively prevents any cooling movements of air from reaching the operators. It is always difficult to obtain suitable labour for this work and high wages have to be paid. The fumigant itself is dangerous to handle and to be landed in north Queensland is expensive. The cost of material, labour and the slowness of the work—one man is doing well if he fumigates half an acre per day—combine to make this method of control very costly, and yet the farmer may be compelled to fumigate or lose most of his standing crops and the valuable ratoons.

During the past few years many hundreds of compounds have been tried against the white grub, but it was not until benzene hexachloride became available to workers in Queensland that anything more promising than carbon disulphide appeared.

The effectiveness of this new compound has been amply demonstrated over the past two seasons, and definite recommendations have been formulated for its use. Figure 1

Figure 1.
Effect of treatment for control of white grubs. The three central rows of Badila cane were treated with benzene hexachloride (1·3 lb. γ isomer per acre). The rows on the right were treated with D.D.T. and, as can be seen, it proved inefficient.

illustrates the kind of result obtained in the field as the result of the control of white grub in north Queensland. The difference in growth is obvious, but not so apparent is the fact that plants in rows treated with benzene hexachloride still had green leaves, whilst in the other rows they were brown and dead.

Experiments on Toxicity of Benzene Hexachloride for Sugar Cane.

In view of the great promise shown in preliminary trials with this new insecticide, extensive tests were carried out to determine whether it had any toxic action on sugar cane. These tests showed that when applied in contact with the cane setts, even at comparatively small rates per acre, while it had no observable effect on the germination of the shoot buds, it inhibits the production of both primary and secondary roots. The roots terminate abruptly when they come into contact with the benzene hexachloride and show characteristically thickened blunt ends. Fortunately, when benzene hexachloride is mixed with the soil prior to planting it requires comparatively heavy applications (more than 40 lb. of crude benzene hexachloride per acre) to cause an observable depression in growth. Applied to the surface of the soil some time after the cane is planted, and worked in with normal cultivation, no depression in growth has been noticed with dressings up to 60 lb. of the crude chemical per acre. Since it appears that only 10 lb., or even less, per acre of benzene hexachloride (with 13 per cent. γ isomer) is required to give effective control of the grubs, there seems little likelihood of damage to the plant provided the material is not applied directly on the cane setts.

Effect of the Different Isomers.

To determine whether the elimination of any particular isomer would have any effect in reducing the phytotoxicity of the crude benzene hexachloride, experiments in plots and in the field were carried out with applications ranging up to 40 lb. of the pure isomer per acre. Samples of α, β, γ and δ isomers were used in addition to a

product called " S.G. 220 ", which contains 20 per cent. γ isomer and is relatively free from the α and β isomers. Although these tests are not complete, it has been established that considerably heavier applications of the γ isomer are possible by using " S.G. 220 " or pure γ isomer than by using crude benzene hexachloride. In other words, the phytotoxicity appears to be determined by the amount of the crude product and, in consequence, the higher the percentage of γ isomer the greater is the rate of application of that isomer which is possible without phytotoxic effects. However, concentrating the γ isomer in benzene hexachloride greater than 13 per cent., or eliminating any of the other isomers, makes the product more costly. In Figure 2

Figure 2.
Rooting system of sugar cane from pots treated with equivalent amounts of the γ isomer (13 lb. per acre) but varying amounts of benzene hexachloride.

are shown the rooting systems of cane grown in pots with equivalent amounts of γ isomer (13 lb. per acre), but owing to different isomer contents differing amounts of benzene hexachloride. In noting the results of this trial it should be mentioned that the quantity of γ isomer per acre is equivalent to ten times the amount recommended for the field dressings with " Gammexane ". It will be seen that the crude material has caused considerable stunting, the pure γ isomer and " S.G. 220 " have caused no loss in vigour.

Retention of Effectiveness of " Gammexane ".

There is no doubt that " Gammexane " has remained effectively toxic in field trials in north Queensland for periods of up to six months. It has not yet been established whether an application to the plant crop will retain its effectiveness for the ratoon crop; this would necessitate it remaining toxic for thirteen to sixteen months. In England some indication has been obtained that the material is effective against wireworms in the second year after application, but conditions in north Queensland are much more extreme and it is impossible to predict behaviour on the basis of English tests.

In small-cage trials with adults of *Dermolepida albohirtum* soil containing one part of γ isomer per 100,000 parts of soil was found to give as effective control when 15 months old as did freshly mixed material. On the other hand, with a concentration of one part per million, the 15 months old mixture caused definitely slower mortality than soil brought to the same concentration with fresh insecticide. The minimum effective concentration for control of these beetles with the fresh material is about one part of the γ isomer for two million parts of soil. There are indications that a comparatively light application in the second year will raise the toxic level to its original value but of course that does not imply that the same thing would hold for succeeding years.

Recommendations.

Despite the fact that grub infestations in north Queensland last season were light, and the information gained from an extensive series of trials meagre, sufficient knowledge has been gathered over the past two years to enable definite recommendations being made for the control of this white grub in cane fields. The rate recommended is 100 lb. of 10 per cent. " Gammexane " dust (1·3 lb. of the γ isomer of benzene hexachloride) per acre. There is, however, good evidence to show that dosages of 75 lb. per acre will prove effective in some instances, and even 50 lb. per acre may have value on the heavier classes of soils. For plant cane, the dust should be applied to the surface of the soil over a band 15 to 18 inches wide along the drills after the cane has germinated and become well established. There is some evidence to show that if the dust is broadcast over the total area of row and interspace equally good results are obtained. It should then be covered by cultivating implements such as the scarifier or cotton-king. It is preferable to apply the dust before the field is worked level and so concentrate the dust near the base of the stools at the time grubs commence to attack the cane roots. Dusting can be fitted in with routine cultivations and can be made at any time between August and November, but preferably at least a month before the anticipated beetle flight. Applications made at varying times after the flight have not proved entirely successful, although in some instances some measure of control has been achieved. Experience with ratoon crop has been rather limited, but it is suggested that furrows be opened on each side of the rows, the dust applied, and the furrows covered.

Farmers in " grubby " areas have taken a keen interest in the experimental work on " Gammexane " and 120 tons of the 10 per cent. dust will be available for application this year. This will enable about 2,700 acres to be treated and should a normally severe grub infestation occur, provide sufficient evidence of the value of the new insecticide for north Queensland conditions.

Acknowledgements.

The benzene hexachloride used in the above trials was kindly supplied by Imperial Chemical Industries Ltd. of Australia and New Zealand. For the field trials this consisted of No. 10 " Gammexane " dust, which is a 10 per cent. mixture of crude benzene hexachloride with pyrophyllite and contains 1·3 per cent. γ isomer. The four isomers used in the phytotoxicity trials were supplied in pure form by the same company.

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Molybdenum and Other Fertilizers in Pasture Development on the Southern Tablelands of New South Wales

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The climatic conditions over most of the tablelands of south-eastern Australia are favourable for the development of improved pastures of subterranean clover and *Phalaris tuberosa*. Within this region, an extensive area is topographically suitable for pasture improvement, but little of this yet carries satisfactory sown pasture. The experiments reported herein were conducted on the Southern Tablelands of New South Wales, including the Australian Capital Territory.

Experiments previously conducted at the Dickson Experiment Station, Canberra, have indicated the importance of trace elements for pasture development in the area. Shaw, Barrie and Kipps[7] have reported a response of lucerne to molybdenum on the Dickson loam in pot cultures. More recently Kipps[5] has shown that high concentrations of available manganese in this soil cause manganese toxicity of lucerne, and that the condition can be alleviated by the application of lime.

During 1946 trials were established in the field on two soil types at the Dickson Experiment Station, and on eleven sites in the Southern Tablelands in the Young, Boorowa, Crookwell and Goulburn districts. The fertility of the soils and the pastures of the area vary widely and are clearly influenced by the nature of the parent material from which the soils are formed. Sites for trials were selected on soils of sedimentary, granitic and basaltic origin.

Experimental.

At the Dickson Experiment Station fertilizer treatments were broadcast by hand on established sown pastures of subterranean clover-*Phalaris tuberosa*-lucerne and of subterranean clover-Wimmera ryegrass respectively.

At all other centres the fertilizers were raked into the soil with seed of subterranean clover and *Phalaris tuberosa*.

Treatments, consisting in the use of 1 cwt. of potassium sulphate per acre, 7 lb. of copper sulphate per acre, 7 lb. of zinc sulphate per acre, $3\frac{1}{2}$ lb. of borax per acre, 2 oz. of molybdenum trioxide per acre, and a mixture of 56 lb. of magnesium sulphate, 14 lb. of manganese sulphate and 14 lb. of ferrous sulphate per acre were tested at all centres in a 2^6 factorial unreplicated trial of 64 plots. A basal dressing of 3 cwt. of superphosphate per acre was applied to all plots at sowing in 1946 and a further basal dressing of 2 cwt. of superphosphate per acre was applied in 1947. Each plot was 15×20 links.

At each centre, trials were also laid down to test the effect of a mixture of the eight mineral elements listed above in the presence and absence of lime, wood ash, nitrogen, and different levels of phosphate.

Results.

The spring of 1946 was particularly dry and growth in the year of establishment was very poor. No significant responses to elements other than phosphate were obtained in that year. However, some improvement in the colour of subterranean clover where molybdenum was applied was observed during the spring of 1946 in a trial at the Dickson Experiment Station.

TABLE 1.

Effects on Botanical Composition and Yield of Pastures in the Southern Tablelands, due to
(i) 2 oz. of molybdenum trioxide per acre (Sections A-C).
(ii) 2 oz. of molybdenum trioxide per acre and 1 cwt. of potassium sulphate per acre, alone and in combination (Section D).

(Dry matter in cwt. per acre.)

A. Dickson Experiment Station—Soil Type 2—Harvested October 8 and November 5, 1947.

Treatment.	Subterranean Clover.	Wimmera Ryegrass.	Other Non-Legumes.	Total.
First harvest—				
Without molybdenum ..	25·20	0·70	1·31	27·21
With molybdenum ..	*36·94	0·51	0·60	38·05
Second harvest—				
Without molybdenum ..	34·10	0·73	1·79	36·62
With molybdenum ..	*40·14	0·54	0·94	41·62

B. Dickson Experiment Station—Soil Type 1—Harvested November 18, 1947.

Treatment.	Sub-terranean Clover.	*Phalaris tuberosa.*	Lucerne.	Other Non-Legumes.	Total.
Without molybdenum ..	7·44	9·45	5·77	0·38	23·04
With molybdenum ..	*13·58	8·87	5·41	0·36	28·22

C. On the Property of Mr. J. C. Mason, "Castlesteads", Boorowa. Harvested November 12, 1947.

Treatment.	Subterranean Clover.	*Phalaris tuberosa.*	Other Non-Legumes.	Total.
Without molybdenum ..	65·01	6·24	0·03	71·28
With molybdenum ..	*71·64	6·43	0·01	78·08

D. On the Estate of A. W. Ranken, "Lockyersleigh", Carrick—Harvested December 12, 1947.

Treatment.	Subterranean Clover.	*Phalaris tuberosa.*	Miscellaneous.	Total.
Nil	3·63	0·08	14·18	17·89
Molybdenum	*7·68	0·07	13·85	21·60
Potassium	†8·33	0·03	14·00	22·36
Molybdenum+potassium ..	*†11·08	0·02	12·46	23·56

* Increases due to molybdenum significant at $P<0.001$.
† Increases due to potassium significant at $P<0.01$.

In the following year, a marked effect of molybdenum on the colour and growth of subterranean clover was observed in the same trial by early July, and statistical

analysis of estimated yields showed that the effect on growth was highly significant ($P<0.001$).*

In the course of the season responses of subterranean clover to molybdenum were recorded on both soils at the Dickson Experiment Station ; in a trial on the property of Mr. J. C. Mason, " Castlesteads ", Boorowa ; in a trial near Goulburn on soil of sedimentary origin on the property of Mr. A. T. Charles, " Rosedale ", Kingsdale ; and on soil of granite origin on the Estate of A. W. Ranken, " Lockyersleigh ", Carrick (Table 1).

Figure 1.

Showing untreated plots and plots treated with two ounces of Molybdenum trioxide per acre in a trial on subterranean clover at Dickson Experiment Station.

Due to the strong competition by native perennial grasses, the establishment of subterranean clover was very poor in the trial at Kingsdale. An effect of molybdenum on the colour and growth of individual plants was observed ; plant diameters were measured on all plots and found to have been significantly increased by treatment, from 21 to 27 inches.

Subterranean clover was nodulated on both control and treated plots at all centres where responses to molybdenum were obtained.

Lucerne, which was present in one of the trials at Dickson Experiment Station, did not respond to molybdenum (Table 1B) and the grasses and other non-legumes did not respond to molybdenum in any of the trials where nitrogen was not applied.

In the subsidiary trials at both the Dickson Experiment Station sites, where sulphate of ammonia and a mixture of elements including molybdenum were tested alone and in combination, the effects and interaction of the treatments on the yield of the sown grasses were significant (Table 2). The responses of Wimmera ryegrass and *Phalaris tuberosa* to the mixture of elements occurred only where sulphate of ammonia was applied. The full significance of this finding remains to be determined.

On the soil derived from granite, at Carrick, subterranean clover responded to both potash and molybdenum (Table 1D). The yield of subterranean clover was increased in this trial by treatment with potash and molybdenum together from 3·6 to 11·1 cwt. of dry matter per acre.

* Well defined plot boundaries occurred between the pale green, untreated clover and the dark green plants treated with molybdenum. Wet sawdust was used to prevent the spread of fertilizer by wind on to neighbouring plots. This method of application has overcome a serious difficulty previously encountered in field trials with molybdenum.

No responses to copper, zinc, manganese, iron, magnesium or boron were obtained in any of the trials.

TABLE 2.

Showing the Effects of 10 *cwt. of Sulphate of Ammonia per Acre and a Mixture of Mineral Elements including Molybdenum on the Yields of Wimmera Ryegrass and* Phalaris tuberosa *Growing in Association with Subterranean Clover at the Dickson Experiment Station.*

(Dry matter in cwt. per acre.)

Treatment.	Wimmera Ryegrass. Trial on Soil Type 1.		*Phalaris tuberosa.* Trial on Soil Type 2.	
	Without Nitrogen.	With Nitrogen.	Without Nitrogen.	With Nitrogen.
Without mineral elements	1·54	2·04	8·97	10·53
With mineral elements* ..	0·12	†6·25	5·12	‡24·62

* See text.
† Effects and interaction significant at $P<0.05$.
‡ Effects and interaction significant at $P<0.01$.

Discussion.

Fertilizer treatments were not repeated in 1947, and in all cases the responses obtained were due to the treatments applied in the autumn of the previous year.

The nature of the responses of pasture to molybdenum so far obtained in the Southern Tablelands are similar in most respects to those obtained previously in South Australia.[1] The present results were obtained with 2 oz. of molybdenum trioxide per acre, and dressings of 1 oz. per acre would probably be sufficient.

The improvement obtained in the colour and growth of subterranean clover with molybdenum indicates an increase in symbiotic nitrogen fixation. In a trial at the Dickson Experiment Station (Table 1B) the well-developed, dark-green subterranean clover treated with molybdenum contained 3·37 per cent. of nitrogen, while the untreated paler green subterranean clover contained only 2·46 per cent. of nitrogen. The importance of molybdenum for symbiotic nitrogen fixation has been described previously.[3]

The soils are distinctly acid, lying for the most part between pH 4·5 and 6. It has been shown that on an acid soil in South Australia, where clovers respond to molybdenum, lime stimulates symbiotic nitrogen fixation by increasing the availability of molybdenum in the soil.[2] Preliminary results at the Dickson Experiment Station indicate that the effect of lime on colour and growth of subterranean clover is similar to that of molybdenum. Whiptail disease of cauliflower, which has been controlled by lime, can also be controlled by molybdenum.[4, 8]

Effects of molybdenum in reducing toxicity symptoms induced in flax by high levels of manganese, zinc, copper, nickel or cobalt have been reported recently by Millikan,[6] and these results are of considerable significance in relation to the soils now under discussion. Since both molybdenum deficiency and manganese toxicity are known to occur on soils at the Dickson Experiment Station, the possibility of an interaction between these two elements is under investigation. Indeed evidence of an interaction between manganese and molybdenum similar to that described by Millikan has already been obtained in this laboratory on a New South Wales coastal soil. However, it is considered unlikely that responses of subterranean clover to molybdenum at the Dickson Experiment Station are primarily due to the prevention of manganese toxicity. Results so far suggest rather that the poor growth of this clover is due to a deficiency of available molybdenum leading to nitrogen deficiency.

Preliminary investigations indicate that the molybdenum content of the plants is particularly low.

Millikan,[6] while noting that chlorosis of legumes has been attributed to nitrogen deficiency due to faulty symbiotic nitrogen fixation, points to a general similarity between molybdenum deficiency and manganese toxicity symptoms in plants. He has also suggested that the difference in responsiveness of grasses and legumes to molybdenum is probably due to a difference in the normal molybdenum requirements of these two types of plants as legumes have been shown to have a much higher content of molybdenum than grasses.

It is considered that clear evidence is available in Australia to show that molybdenum response by legumes may be due wholly to improved nitrogen fixation, and that Millikan's observations do not provide a satisfactory alternative explanation of legume responses in cases where the nature of the responses has been studied.

In pot culture studies on Burbrook sandy loam from Meadows, South Australia, the following points led to the acceptance of the hypothesis that the molybdenum response on this soil is due almost entirely to an increase in symbiotic nitrogen fixation.[3] The nitrogen content of the Burbrook sandy loam is very low, and on this soil normally nodulated clovers not treated with molybdenum were poorly developed and nitrogen deficient. Plants treated with adequate sulphate of ammonia were well developed and a healthy dark green colour. Sulphate of ammonia decreased the molybdenum content of the plants, yet growth was enormously enhanced. Nitrogen was undoubtedly a limiting factor for the growth of the host legume on untreated soil, even though the plants were abundantly nodulated. Molybdenum increased the absolute amount and percentage nitrogen in the plants in all cases where it increased the yield, and molybdenum treated plants were not nitrogen deficient. The increase in nitrogen supply was not due to an increase in the amount of soil nitrogen available to the growing plant, but to an increase in symbiotic nitrogen fixation.

A particularly interesting feature of the responses obtained at the Dickson Experiment Station was the observation that the colour and rate of growth of untreated subterranean clover improved markedly in the spring and summer months. A comparison of yields at two harvests during 1947 on the Dickson Experiment Station is given in Table 1A. It is suggested that accelerated nitrification in the soil during the warmer months tended to reduce the dependence of the clover on symbiotic nitrogen fixation.

Marked responses to superphosphate were obtained at all centres, and responses to molybdenum can only be expected where superphosphate is applied. At the Dickson Experiment Station, where the interaction was tested, responses to molybdenum were observed only where superphosphate was applied.

On account of the marked variation in rainfall during the growing season on the Southern Tablelands, the response to fertilizers will vary considerably from year to year, and trials in this region must be continued for a number of years before a final evaluation of the responses can be obtained.

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The Need for Destructive Criticism

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I want to rouse your interest in a matter that is vital to the progress of science; in short, that a great deal of bad work gets published today, and most of it escapes criticism. I want you to consider why this happens and whether it has always been so, and to urge that we should do something about it. My examples of bad work will be taken from articles on soil, since that is my own special interest; but the trouble is general.

Exhibit A, Cooper[1] in 1929 put forward a theoretical explanation of the order in which plants absorb elements from the soil—more potassium than magnesium, more magnesium than iron, and so on. Cooper's theory, expressed in simpler terms than he uses, is that the more difficult it is to reduce an element to the metallic state the easier it is for a plant to absorb it. Strangely enough, this works as an empirical rule for those three, potassium, magnesium, and iron, though it breaks down when sodium is added to the list (difficult to reduce, and absorbed only in small amounts). Theoretically this rule simply does not make sense, since these elements are not present in the metallic state at any stage. And yet nobody in these eighteen years has written any article pointing out that the whole of this theory is plain rubbish.

This is an extreme case and is interesting to follow further. A lot of workers realize that it is all wrong, and when they write about the intake of elements by plants they simply ignore Cooper's theory. This is one method of dealing with bad work: take no notice, get on with your own job, and trust that the good will survive. (For example, this has been the attitude of scientists in general towards the compost cranks.) However, consider the consequences. If the author of bad work has to read an analysis of his theory in a good journal, he will not be likely to repeat his offence. But as it was, two years ago the publishers of *Soil Science* brought out a special number on Minor Elements. This was a great event, an opportunity to put forward new ideas and suggest promising lines of work as well as to review the present state of knowledge. Cooper was invited to write the article on magnesium, so there is his theory repeated again, side by side with the work of the great geochemist Goldschmidt, and so given as it were official sanction. One page of published criticism would have prevented all that.

Exhibit B is a paper by Somers and Shive,[2] which has had a great deal of attention. The theme is that iron and manganese have antagonistic effects on plants. There is no doubt that this is true for some plants over some ranges of concentration. Somers and Shive show this and invent a fallacious theory to account for it. The theory is that because it is more difficult to oxidize manganous salts than it is to oxidize ferrous salts, the presence of manganese causes ferrous salts to be oxidized. It is not put like that, but is expressed in terms of oxidation-reduction potentials, and readers have evidently thought " how erudite " and have not pursued

(Read at the meeting of the A.N.Z.A.A.S., Perth, August 1847.)

the argument further. This nonsense has been solemnly quoted in many places, and again has never been exposed except in a not very well-known Australian journal. This is more serious than Cooper's work ; it is *not* ignored and has muddled a lot of minds.

Incidentally, leaving aside the theory, the claims in their paper are greatly exaggerated. They say that the ratio of iron to manganese in solution must be " within a narrow range round 2 " for plants to be healthy. Their figures show ratios of 50 and 0·6 as the nearest at which plants are not healthy.

Exhibit C raises another issue. Heintze,[3] dealing with manganese deficiency disease, makes two clear statements within six lines ; firstly, that three parts per million of exchangeable manganese is the average amount present in deficient soils, and secondly, that three parts per million is the maximum amount present in deficient soils. This may have been merely a slip ; but an editor ought not to allow a mistake like this to pass. The bad stuff should never get into the journals in the first place. In the long run—whether through referees or not—editors are responsible, and I would have no hesitation as editor of a chemical journal in sending back any article containing the abovementioned theory of Somers and Shive. But as far as I can see, many editors either do not suspect how bad their articles are, or if they do are too timid to reject them. They are afraid of the argument, " Beethoven's contemporaries didn't appreciate him, and for all you know here you are rejecting another great man ". If editors are afraid to reject, then the readers of the journal have to take the responsibility themselves. This applies to more than merely fallacious theories ; public criticism is just as necessary when an author misquotes other people's work, usually through using an abstract instead of reading the original. In all these cases if criticism were more common the fear of public exposure would have an excellent effect.

Not many scientists today are willing to write in critical terms for a journal. It was not always so. I would be the last person to praise the " good old days " at the expense of our own, and I recognize that the decline of polemical writing during this century coincides with a general improvement in manners, but we have lost a lot through not having discussion of papers in print.

Take the *Journal of Physical Chemistry* in the early years of the century. Bancroft then used to write short abstracts of current literature which were more than abstracts, they assessed the work. Here are a few examples (1906) :

> " It would add greatly to the value of this series if some physical chemist would look over the manuscript and cut out misleading or inaccurate statements."
>
> " Beckmann claims that the method of direct heating with a flame gives the most accurate results. This would be more convincing if it were not for Beckmann's failure to notice work which controverts this."
>
> " The paper is hard reading."
>
> (On a claim to have isolated two different ferric sulphates of the same total composition.) " Since the author has not determined what constitutes the real difference in the two cases the work will have to be done again."

This is delightful. Unfortunately, this job became too big. In 1907 *Chemical Abstracts* was founded, to give merely factual abstracts, and Bancroft's reviews disappeared.

What is the matter today ? There is a widespread feeling amounting to a convention in the English-speaking world, that destructive criticism is not nice—it's the sort of thing that no Old Boy of any really decent school would ever do. Of course no one would defend mere fault-finding, by which I mean the childish way in which some people pick on trivial details in expression or in an experiment and make a great fuss about them. And no one would defend any attacks made on grounds of personal spite. People who say that destructive criticism is wrong sometimes point

to such petty kinds of criticism to support their case. All this is beside the point. I am thinking of the need both for destroying fallacies and for compelling workers to do their work competently or abandon the field. How silly the argument is, that you mustn't criticize unless you have something constructive to say ! As a chemist, I might see that a theory used by physiologists was wrong, and point out that part of the theory was incompatible with some well-established principle in chemistry. If the physiologist is sensible he won't complain that this was purely destructive and ask me what I am going to put in its place. It is not the critic's job in science, or in anything else, to put anything in its place. If he can see a fallacy where no one saw it before, he has done a great service. Of course, if he merely points out a theoretical weakness that everyone is aware of, he is being a bore—that is not criticism.

One other restraining force in writing critical letters or articles is the thought that the victim might not like it. This is a poor reason for not helping the progress of science. If the person whose opinions are criticized takes it badly, I doubt if his goodwill was worth having. One can be good-mannered and critical at the same time. Many journals, too, have played their part badly by discouraging review or discussion articles, and asking only for original work. There are far too many articles that are merely competent reports and no more, and far too few that discuss a subject—in soil science the number is negligible. Incidentally, a large proportion of so-called reviews are not reviews at all but merely collections of references to the literature.

My chief plea is that we should tackle the editors who allow bad work to pass. If a theory can be shown to be fallacious, if a claim to originality can be shown to be false, the correction ought to be published in the journal in which the offending article appeared. To admit a letter of criticism means a change in policy in some journals, and it may take persistent pressure to force such a change. But if we as individual scientists will play our part, we should succeed in raising the standard of our journals.

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Technical Notes

THE COEFFICIENT OF VARIATION OF WOOL FIBRE FINENESS WITH AGE AND FLEECE SITE.

In considering fibre fineness variability, it is common to resort to the measurement of staples from one or more fleece sites, rather than to attempt the less convenient practice of carding the whole fleece to produce comparative homogeneity and then to extract representative samples from it. Reimers and Swart[5] have given a number of frequency distributions of fibre fineness of staples from various fleece positions on merino sheep and there is a marked similarity in the general shape of the frequency curves derived for different positions on the same sheep. Similar measurements in this laboratory appear to confirm this impression. It is of direct interest, when analysing the results of the combination and intermingling of staples of given variability into a " straight type " for topmaking, to know if wools from different sites in the same fleece have approximately the same variability. The breeder is also anxious to know whether the fineness variability of wool from the same site on the same sheep in different seasons is constant or not. It has been shown by Lang[3] that certain changes may occur in the fineness frequency distribution when the thickness-rate-of-wool production is altered by unfavourable changes of nutrition, animal ill health, etc. These may cause the coefficient of variation to alter—therefore in studying the variability of the same fleece site in different years it is necessary to be assured that the plane of nutrition of the sheep concerned has been approximately the same.

The coefficient of variation has been used widely as a measure of variability, although it is not entirely satisfactory for this purpose. However, no completely satisfactory coefficient has been proposed in its place. It is therefore proposed to follow the usual practice and discuss variability in terms of the coefficient of variation. It has been found[4] that the coefficient of variation for merino sheep may vary from 10 per cent. to 41 per cent. approximately, although for practical purposes the limits 10 per cent. to 30 per cent. cover the majority of samples from this breed.

Coefficients of Variation of Fibre Fineness of Staples from Shoulder and Breech Sites of the Same Fleece.

Sets of Merino and Corriedale samples of the above description have been given in Tables 1 and 2, for which the correlation coefficients are 0·61 and 0·63 respectively.

TABLE 1.

Coefficient of Variation of Merino Staples from Two Sites of the Same Fleece.

Shoulder. Coefficient of Variation Per Cent.	Breech. Coefficient of Variation Per Cent.												
	12	13	14	15	16	17	18	19	20	21	22	23	
12				1	1								2
13		2	1	1	1	–	2						7
14	1	–	4	5	1	–	3						14
15			3	5	6	3	–	1	1	2			21
16				3	7	2	2	1					15
17			1	2	3	2	3	4	–	1	1		17
18					2	1	2	2	3	1			11
19						1	–	1	2	1	–	1	6
20									1				1
21							1	–	–	1			2
22													—
23												1	1
	1	2	9	17	21	9	13	9	7	6	1	2	97

Correlation coefficient—0·61.

The coefficients of variation have been calculated following 250 measurements at 500 diameters magnification ; the conditions of mounting described by Bosman and van Wyk[2] being observed. All staples were sampled across the proximal end.

TABLE 2.

Coefficient of Variation of Corriedale Staples from Two Sites of the Same Fleece.

Shoulder. Coefficient of Variation Per Cent.	Breech. Coefficient of Variation Per Cent.																	
	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
13		1		1															2
14			1									1							2
15		1	3	3	1	–	1												9
16	1	1	1	2	1	2	1	1	2										12
17		1	1	–	–	1	1					1							5
18			1	–	1	–	–	1	–	3									6
19						3	2	1	1	–	–	1	1			1			10
20					1	2	1	–	1	1	1	1							8
21					1	–	1	–	1	–	–	–	1						4
22								2	1	1									4
23													1						1
24							1	–	1										2
25																		1	1
26											1								1
27																1			1
28									1										1
	1	4	7	6	5	8	8	5	8	5	2	4	3	–	–	2	–	1	69

Correlation coefficient—0·63.

Coefficients of Variation of Fibre Fineness of Staples from the Mid-side Position in Two Different Seasons.

Single staples, from a fleece site three inches behind the heart girth and a hand span from the mid-line of the back, were obtained from merino sheep at " Noondoo " near Dirranbandi by the courtesy of Mr. Euston Young, Manager of the Australian Pastoral Company. These represented :

(*a*) Stud ewes at both the 2-tooth and 4-tooth stages.

(*b*) Stud ewes at both the 2-tooth and 6-tooth stages.

The wool had been well grown on each occasion and the mean fineness was approximately the same, confirming the assumption that the plane of nutrition had not been changed unduly. All staples were sampled across the proximal end.

This was believed to avoid any difficulty in 2-tooth samples, associated with the incomplete development of fibre thickness during the non-adult stage. Bosman,[1] reporting Botha, has suggested that after the age of seven months stabilization of the thickness-growth-rate may be assumed. Tables 3 and 4 express these results.

In the first case, that of the relationship of shoulder and breech samples, a high positive correlation exists, whereas in the latter a moderate positive correlation only has been obtained. While it is acknowledged that only two fleece positions have been recorded in the former, there is nothing to suggest that other fleece positions would have led to a different conclusion. The result would imply that inasmuch as the follicle groups are basic to staple formation, and depend for their individuality on the relationship of primary and secondary follicle development, the pattern of wool production in different fleece sites on the same sheep has the elements of similarity. In the latter case, that of wool from the same site at different ages, the similarity is less marked, suggesting, if the assumption concerning the constancy of nutritional plane has been correct, some change in the relationship of the follicles with respect to thickness-rate of production.

TABLE 3.

Coefficients of Variation of Merino Staples from the Mid-rib Position of the Same Animal at the 2-Tooth and 4-Tooth Stages.

2-Tooth Stage. Coefficient of Variation Per Cent.	4-Tooth Stage. Coefficient of Variation Per Cent.											
	12	13	14	15	16	17	18	19	20	21	22	
13			1		1							2
14												—
15					4		1					5
16	1	—	—	2	3	1						7
17			1	—	—	2	1	3	2			9
18				1	3	—	3	—	1	1		9
19			1	—	1	—	1	4	1	1		9
20			1	1	—	1	—	—	1	—	1	5
	1	—	4	4	12	4	6	7	5	2	1	46

Correlation coefficient—0·40.

TABLE 4.

Coefficients of Variation of Merino Staples from the Mid-rib Position of the Same Animal at the 2-Tooth and 6-Tooth Stages.

2-Tooth Stage. Coefficient of Variation Per Cent.	6-Tooth Stage. Coefficient of Variation Per Cent.																
	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	
14					1												1
15	1	—	1	—	—	1	—	1	—	1	—	—	1				6
16					1	3	2	2	2	1	—	1	—				12
17				1	1	1	3	—	2								8
18				1	4	2	5	—	2	—	—	—	—	1			15
19			1	—	—	1	3	1	—	—	—	—	1				7
20			1	1	—	—	1	—	3	2	1						9
21			1	—	1	1	2	2	1								8
22										1	2	—	1				4
23						2						1	—	—	—	1	4
24									1	—	—						1
25					1												1
26									1	—	1						2
	1	—	4	3	9	11	16	6	12	5	5	2	3	1	—	1	79

Correlation coefficient—0·30.

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LIME IN RELATION TO CLOVER NODULATION AT SITES ON THE SOUTHERN TABLELANDS OF NEW SOUTH WALES.

The nature and location of field trials established in the autumn of 1946 on the Southern Tablelands of New South Wales have been described in a previous paper, and responses of subterranean clover to molybdenum and potash on certain soils have been reported.* It has also been noted that subterranean clover, whether treated or untreated, was well nodulated where responses to molybdenum were obtained.

However, at six of the sites in the Southern Tablelands a large proportion of the subterranean clover plants on unlimed plots were completely lacking in nodules, in spite of the fact that the seed was inoculated before sowing. This problem of defective nodulation occurred in varying degrees of severity at five centres on soils of sedimentary origin; viz. at Pomeroy, Grabben-Gullen, Laggan, Kingsdale and Murringo; and at one centre on soil of granitic origin, at Tarago. The trials at Pomeroy and Grabben-Gullen were located on land where previous attempts by landholders to establish subterranean clover had failed completely.

Figure 1.
Showing well developed subterranean clover on small ash patch (centre) and typical partially cleared country (background) at Grabben-Gullen.

In the year of establishment, 1946, nearly all of the plants lacked nodules and were stunted and yellow at all six centres. At Pomeroy and Laggan some nodulated plants were found on the lime treated plots, but none on the controls. However, no improvement in growth due to the lime could be detected. At the remaining centres no effect of lime on either growth or nodulation was obtained. A few small, isolated, patches of normal, dark green clover, invariably well nodulated, occurred on the trials (Fig. 1). These patches were erratically distributed and were not associated with any specific treatment. An obvious concentration of charcoal was often found on the ground at these patches.

* This volume, page 28.

The rainfall in 1946 was particularly low during the spring, and this may have adversely influenced the nodulation of the plants. However, lack of nodulation cannot be attributed entirely to low soil moisture conditions, since well nodulated plants occurred on the ash patches referred to and on neighbouring, normal soils.

Figure 2.
Showing well developed, nodulated subterranean clover on a plot treated with lime, compared with stunted, unnodulated plants on a plot without lime (foreground) at Pomeroy.

In the following year the rainfall in the spring was much more favourable, and responses to lime were obtained at all six centres (Table 1 and Fig. 2). The clover on all plots treated with lime was well nodulated and dark green. At Grabben-Gullen and at Pomeroy the yields of subterranean clover were increased from less than 1 cwt. per acre in each place to nearly 1 ton per acre and to 2 tons per acre respectively. Plants on the unlimed control plots at these two centres were unnodulated, stunted and yellow. At Laggan and Tarago both normal, nodulated plants and stunted plants without nodules occurred on the control plots, whereas on the limed plots all plants were normal.

TABLE 1.
Effects of 10 Cwt. of Lime per Acre on the Yield of Subterranean Clover at Centres where Defective Nodulation Occurs.
(Dry matter in cwt. per acre in the second season, 1947.)

	Location.				
	Pomeroy.	Grabben-Gullen.	Tarago.	Laggan.	Murringo.
Without lime	0·84†	0·88†	5·89‡	20·90‡	24·62§
With lime*	40·30§	19·45§	12·42§	56·17§	37·18§

* All increases due to lime, highly significant.
† No nodules present in 1947.
‡ Some plants nodulated in 1947.
§ All plants nodulated in 1947.

The establishment of clover at Kingsdale in trials laid down in 1946 was very poor, and yields were not determined. A marked, but undetermined effect of lime was observed in 1947. In that year, at Murringo and Kingsdale, the subterranean clover was nodulated on both control and lime treated plots, at least by the end of the season. Most of the plants on both limed and unlimed plots lacked nodules in the previous year. During 1947 it was noted at Murringo that the proportion of nodulated plants on adjacent unlimed areas increased as the season advanced. It is therefore possible that the effect of lime at these centres may have been due in part to promoting earlier nodulation. It is not yet known whether the better nodulation of untreated plants in the second season was due to a general improvement with time, or to the better rainfall conditions during spring months.

Additional evidence of the effect of lime on nodulation was obtained in a trial established a year later, during 1947, on a soil of sedimentary origin at Middle Arm. The trial was designed to determine the effects of lime, phosphate and trace elements when applied alone and in combination. Little benefit was obtained with lime or phosphate applied alone, but in the presence of lime at the rate of 1 ton per acre, the response to superphosphate was very marked (Table 2). Again clover on plots treated with lime was green and well nodulated, while plants on unlimed plots were invariably without nodules and stunted.

TABLE 2.

Effects of Lime and of Varying Levels of Superphosphate, Alone and in Combination, on the Yield of Subterranean Clover—Middle Arm.

(Dry matter in cwt. per acre.)

	Superphosphate per Acre.			
	Nil.	2 Cwt.	4 Cwt.	8 Cwt.
Without lime	0·21	0·66	0·94	0·26
With one ton lime per acre	1·81	7·45	14·90	11·27

Effects of lime and phosphate and the interaction, highly significant.

The reason for the effect of lime on nodulation is not yet understood. The pH of the soils at the sites where the problem occurred varies between 4·0 and 5·4. There is some correlation between the occurrence of the problem of defective nodulation and the pH of the soil ; lack of nodulation usually occurring on soils of the lowest pH. However, many anomalies occurred ; well nodulated plants were found on soil of pH 4·6, and plants without nodules on soil of pH 5·4.

At no centre was nodulation of the clover induced by superphosphate, or by molybdenum, potash, copper, zinc, manganese, iron, boron or magnesium. Since no improvement in nodulation has yet been obtained by treatment with high levels of superphosphate (supplying up to 4 cwt. per acre of gypsum) it seems unlikely that the problem is due to a simple deficiency of calcium. The factors involved in the response to lime must be determined before the need for lime *per se*, or the amounts required can be assessed.

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The Australian Institute of Agricultural Science

MEETINGS OF COUNCIL.

Meetings of Council were held on 2nd December, 1947, and 3rd February, 1948, with the President (Mr. de Vahl Davis) in the chair. At the December meeting Messrs. R. H. Hayman and E. J. Breakwell attended as newly appointed proxies for the Victorian and Western Australian principal delegates, respectively. All other branches were represented at both meetings.

The Chairman reported receipt of a letter from the Hon. General Secretary intimating that he was finding it increasingly difficult to devote the necessary time to secretarial duties and that a suitable successor could be nominated. He wished, therefore, to tender his resignation. Council, with regret, accepted Dr. Bowman's resignation, to take effect as from the conclusion of the next annual meeting.

Award of Merit.—At the December meeting it was resolved that the award of merit to be given by the Institute be called the " Australian Medal of Agricultural Science ".

At the February meeting a series of amendments to the conditions governing the award, of which due notice had been given, were adopted, and the meeting informed that arrangements for the design and striking of the medal, made. Since the February meeting it has been announced that Professor S. M. Wadham, of the School of Agriculture, University of Melbourne, is to be the first recipient of the award.

Financial Position of Institute.—The sub-committee, with the Hon. Treasurer, Mr. F. C. McCleery as convener, appointed to consider finance in terms of the resolution from the Perth general meeting submitted a report to the December meeting. The sub-committee, in its report, considered present and likely future costs of the Journal, general income and expenditure and possible sources of additional funds. It recommended that Council should for 1947 and the future discontinue the payment of grants which have been made to Branches in respect to their membership. The recommendation has since been approved by a majority of Branches.

Journal.—At the December meeting a letter was received from the Hon. Editor, Mr. D. B. Adam, who intimated his desire to resign as from the completion of Vol. 13. The resignation was accepted with regret and it was resolved that a suitable letter be forwarded indicating the appreciation of Council and all members for his services as Editor. The South Australian Branch was invited to nominate a successor, but later indicated its inability to do so. It was suggested that the Publications Committee be transferred to another Branch.

At its February meeting Council accepted this advice and invited the Victorian Branch to undertake the work, to nominate an Editor of the Journal, and a Publications Committee.

Restriction of Import of Text-books.—The Tasmanian Branch drew attention to the reduction of import quotas of scientific books from America to 10 per cent. of the 1947 quotas in the case of universities and 6 per cent. of the same quota in the case of other institutions. It was resolved that a letter be sent to the Prime Minister protesting against the unduly heavy restrictions placed upon the importation of scientific text-books into Australia from the United States of America.

Membership.—The report of the Qualifications Committee for the year 1947 was received. The report of this sub-committee, of which Mr. A. J. Vasey is convener, reveals that during 1947, 63 applications for corporate membership were approved by Council, against 42 for 1946. The position in respect to student membership was even more gratifying, 83 applications being approved for 1947 against eight for 1946.

The following applications for corporate membership have been approved : Messrs. R. D. Brock, C. W. E. Moore (A.C.T.), R. J. Conroy, F. R. Gibbons, Dr. W. C. Hopper, Messrs. H. N. Johnston, J. R. Niccol, H. Praison, L. V. Toyne, K. D. Woodger (N.S.W.), R. W. Mungomery (Qld.), Dr. L. A. T. Ballard, Messrs. M. R. Krause, J. P. Quirk (S.A.), J. M. Croop, W. F. Hosking, J. H. Payne, Miss M. W. Richards, Mr. H. C. Watts (Vic.), and for student membership : Messrs. R. Evans (N.S.W.), K. M. Sillcock (Vic.).

The resignations of Messrs. D. O. Cross and R. S. Mitchell (N.S.W.) and of Mr. O. H. Gepp (Vic.) were accepted with regret.

MEETINGS OF BRANCHES.

Australian Capital Territory Branch.

The 69th general meeting of the A.C.T. Branch was held on 12th December, 1947. The main business of the evening was an address by Mr. J. G. Crawford, Director of Bureau of Agricultural Economics, on the activities of the Bureau. Mr. Crawford explained that the role of the Bureau is to carry out agricultural economic investigations on behalf of any Commonwealth or State organizations, or for primary industry organizations.

The Bureau contains the following five main sections : the General and Statistics, Agricultural Commodities, Wool, Land Use, and Administrative Sections. A brief account of each section was presented.

Mr. Crawford stressed that all work was undertaken along lines determined by the Bureau. Obvious emphasis had been placed in the past on short-term work, but it was hoped that a greater number of long-term investigations would be undertaken in the near future.

New South Wales Branch.

At a general meeting of the N.S.W. Branch held at Science House, Sydney, on 10th October, 1947, Dr. Hopper, of the Canadian Government Trade Commission, spoke on some aspects of present-day Canadian agriculture.

He commenced with a comparison of Canadian and Australian climates, and stressed the difficulties associated with the Canadian winters, when practically all animals are housed for up to five months. In the pastoral areas beef cattle and sheep are not always housed, but must have fodder available in barns. In some areas temperatures fall to 50° Fahr. below zero, which provides all sorts of difficulties for the farming community.

In Canada there are about three-quarters of a million farms covering 175 million acres. Of this area 90 million acres are cultivated—less than 10 per cent. of the total land area of Canada. There is much room for expansion. Average farm size ranges from 95 acres in Prince Edward Island to 432 acres in Saskatchewan.

Canada produces annually £460-600 million of agricultural products. Half of this is exported. Principal exports are wheat, bacon, meat, dairy products and apples. More than two-thirds of these exports go to the United Kingdom. America is the next most important market.

Wheat is being grown on 24 million acres this year. Estimated production is 358 million bushels. The finest bread wheat in the world is grown in western Canada. This has largely been possible by the development of specific varieties which are resistant to or escape the ravages of frost, diseases and pests. Marquis, Thatcher and recently Redman and Rescue are varieties which have had a significant role in the Canadian wheat industry.

Harvested grain is handled in bulk rather than bags. There are 5,500 country elevators in Manitoba, Saskatchewan and Alberta. The elevator operator grades wheat as it is delivered, payment being based on the grade and the distance of local elevator from terminal elevator at Fort William. Canadian Wheat Board purchases all wheat. At present the price of No. 1 Northern is about 8/-, but the farmer also receives a participation certificate representing his share of the additional returns for wheat sold by the Board on domestic or export markets.

Canada is the greatest wheat exporter in the world, which is due in part to the special care paid to grading and handling.

Dairy Products.—Between 17 and 18 billion pounds of milk are produced annually by four million dairy cows. Dairying is distributed widely, but most of the processing plants are in Ontario and Quebec. Milking machines are widely used. Holstein Friesians are the most important breed, but Ayrshires, Jerseys, French Canadian Guernseys and Dual Purpose Shorthorns are also popular.

Pigs.—There are at present about six million pigs in Canada. Pigs are graded on rail after slaughter and producers are paid accordingly. Government premiums are paid for high grade. All meat packed for export and much for home consumption must be passed disease-free. The Yorkshire is the commonest breed. Contracts to supply 400 million pounds of pig products to the United Kingdom in 1948 have been entered upon.

Fruit.—Apples constitute 50 per cent. of the total value of Canadian fruit crops. Minor crops are peaches, pears, grapes, plums and cherries. Berries are produced widely. No citrus or dried fruits are grown. Canada grows her own tobacco requirements.

Dr. Hopper described co-operative business organizations which have grown so widely that a certain proportion of practically every kind of agricultural commodity is sold co-operatively. Marketing acts and schemes apply mainly to milk, fruits and vegetables. Dr. Hopper concluded by stressing the possibilities of future expansion of Canadian agriculture, and of intensification of production on existing farm land.

A joint meeting of the N.S.W. Branch and the N.S.W. Branch of the Australian Society of Dairy Technology was held in the British Medical Association Building, Sydney, on 10th November, 1947. The speakers were Dr. W. M. Hamilton, Research Survey Officer of the Department of Scientific and Industrial Research, N.Z., and Mr. A. H. Ward, Director of Herd Improvement and Statistician of the New Zealand Dairy Board.

South Australian Branch.

A general meeting of the Branch was held on 12th December, when the principal item was an address on " Important Topical Aspects of Tropical Entomology ", by Mr. R. N. McCulloch. The speaker referred to the fact that in 1942 army authorities became so conscious of the importance of insects in relation to disease that six mobile Entomological Units and 32 Malarial Control Units were organized and suitably staffed. Mr. McCulloch worked mainly on the problems of malaria and scrub typhus. In camp areas in N.S.W. where mosquitoes were bad a phthalate repellent supplied by a commercial firm was found to have outstanding value.

Present views on the cause, distribution and epidemiology of scrub typhus were briefly described. D.D.T. did not find much use in relation to this particular problem, but towards the end of the war Gammexane, Benzil Benzoate and Benzil were being tested and found very useful. Gammexane was finding a good deal of use in area disinfection. It might have some future in clearing up mite infestation in populated areas. Mr. D. C. Swan, who did entomological work with the R.A.A.F. during the war, commented briefly on the speaker's address and the high value of Mr. McCulloch's contribution to knowledge.

Current Notes and News

Yanco Experiment Farm.

The Yanco Experiment Farm, Murrumbidgee Irrigation Area, was officially transferred back to the Department of Agriculture on 4th February, 1948, by the Minister for Agriculture, Mr. E. H. Graham. The Farm was established by the Department in 1908 and operated as an experiment farm until 1928, when it was taken over as a welfare farm by the Department of Education. From 1942 to 1945 it was used as a P.O.W. camp, and since that time has been under the control of the Department of Education. An extensive programme of research into all branches of agriculture important in this area is being planned.

Retirement of Mr. C. C. Crane.

Mr. C. C. Crane, first Chief of the Division of Information and Extension Services of the Department of Agriculture of New South Wales, retired from the service last November and Miss Lorna Byrne has supplied us with the following note concerning him.

C. C. Crane will be remembered as the first full-time Organizer of the Agricultural Bureau of New South Wales, a position which he filled from 1919 to 1940, when he was appointed Chief of the Division.

It is always more difficult to rebuild after a period of disruption than to launch and develop an entirely new venture, so when Mr. Crane set off to rebuild the Agricultural Bureau which had completely disintegrated during the years of World War I, he was undertaking no mean task. He worked unceasingly. His diary was crammed full of appointments many months in advance and no distance was too great, no journey too inconvenient for him to undertake in an endeavour to form new branches of the Bureau and encourage keener interest in those already in existence.

Every field officer knew him, and many a young or diffident instructor gained confidence and fresh courage after a session of helpful criticism during a long car drive with C. C. Crane in his district. The farmers and their families grew to know and appreciate him, and they sought his personal and official advice on many and varied problems.

Before joining the Department of Agriculture, Mr. Crane was a teacher of languages in the Department of Education. Later he became house-master at Wagga Experiment Farm. He is convinced that some teaching experience is a great asset to the extension worker. It is probably due to this firm conviction that he made a feature during his latter years in the Department of the training of field officers in all branches of extension work at schools which he personally organized and conducted.

One of his slogans was " Never let the farmer down ", and this he instilled into all officers with whom he came in contact.

Mr. Crane has great faith in the youth of this country and for this reason he fostered schools for citizenship and leadership among the grown-up young people of the New South Wales countryside. Hundreds of young people on farms today remember his talks on citizenship and the value of well-run organizations—his adjudication of debates and his hard, yet kindly criticism of their efforts at public speaking.

He was the obvious officer to be chosen in World War II to administer the War Agricultural Committees in New South Wales. His brilliant achievements in the first A.I.F. combined with his wide knowledge of primary production and producers stood him in good stead during those difficult years of rationing, planning and shortage of labour.

Those of us who worked with Mr. Crane will always remember his unfailing helpfulness and his keen sense of humour. It was a serious business which could not call to his mind an amusing anecdote or an appropriate whimsical comment.

His great hobby has always been gardening and his garden at Pymble, with his collection of flowering shrubs, many varieties of annuals and all types of bulbs, has become known to hundreds of people throughout the State.

Now that he has retired, he has more time to devote to his garden. His other hobby of more recent origin—bowls—occupies much of his time, so much so that he recently remarked to a number of officers, " What with the garden and bowls, I don't know how I ever found time to go to work ".

He has devoted over 40 years to valuable public service, and he has earned a rest.

Book Review

CHEMICAL COMPOSITION OF PLANTS AS AN INDEX OF THEIR NUTRITIONAL STATUS, by D. W. Goodall and F. G. Gregory.

(*Technical Communication No. 17 of the Commonwealth Bureau of Horticulture and Plantation Crops. 1947. 167 pp. Price 9/- sterling.*)

This publication, which has been awaited with considerable interest for some time, has now appeared. Dr. Goodall and Dr. Gregory have performed a very valuable service to research workers in the field of plant nutrition, and they are to be congratulated on the production of such a comprehensive review of the literature dealing with the mineral composition of plants. Some idea of the magnitude of the work is given by the bibliography of over 900 entries and the vast amount of information summarized in 15 tables.

It is pointed out that direct field experiment must remain the ultimate test in judging the value of any method for the determination of the fertilizer requirements of crops. Until predictions founded on any proposed method are confirmed by field experiments the usefulness of the method cannot be established. This criterion of usefulness applies equally to biological and chemical methods. In predicting fertilizer requirements field experiments suffer drawbacks in that the results cannot be used in the year in which the experiments are carried out. One of the aims of a rapid diagnostic method is to enable current nutrient requirements to be predicted. Plant analysis offers a possibility of achieving this before planting time, provided standard values from the analysis of weeds or of a previous crop can be established in relation to the performance of a subsequent crop.

The introductory section briefly mentions the various diagnostic methods of nutrient requirements such as pot experiments, injection methods, and biological and chemical analysis of the soil, including many rapid systems of soil testing. The monograph then sets out to examine the claim that the composition of the plant reflects the adequacy of its nutritional supplies and the probability of its response to additional supplies.

Four large tables summarize most of the available analytical data covering deficient, normal and toxic concentrations of the various elements and indicate the most suitable parts of the plant for analysis. Other sections discuss sampling technique, preparation of material for analysis, methods for the expression and interpretation of results and factors affecting the use of plant analysis for deficiency diagnosis.

That environmental conditions affect the nutrient content of a plant is well recognized. It is stated that this need not affect the diagnostic value of plant analysis. The lowest value quoted for an adequate supply of phosphorus in wheat straw in Table XII appears high in the light of Australian experience of standards derived from crops grown under conditions of no response to applied phosphate. Other factors also lead to unusual concentrations of a deficient element in the plant. Examples are known of an iron chlorosis brought about not by a lack of iron but rather by its immobilization within the conducting tissues of the plant before it reaches the leaves. In this connection much more needs to be known of the effects of the ratio of pairs of elements or even groups of elements on the availability and mobility of the elements within the plant.

An excellent index makes the material readily accessible and it is safe to predict that this publication will prove an indispensable work of reference to all researchers in this expanding field.

C. S. Piper.

THE GRAFTER'S HANDBOOK, by R. J. Garner.

(*Faber and Faber, London. Pp. 223. Price 15/- sterling.*)

This book brings together a great deal of useful information bearing upon the old established art of grafting. The author has worked at the East Malling Research Station for twenty years. The outlook of the book is practical and Mr. Garner, as Dr. Hatton points out in the foreword, " has unconsciously succeeded in portraying himself wielding the tools, materials and methods which he describes so vividly ". The book, with its numerous practical hints, will no doubt be of great use to those already skilled in the art of grafting, to students developing the art, and perhaps most of all to the less skilled who may wish to try their hand at grafting to meet some experimental need ; the transmission, for instance, of some virus disease.

The book is well produced and well illustrated. The clear drawings prepared by the author himself add considerable value to the descriptive text.

D. B. Adam.

Personal Notes

Dr. J. Griffiths Davies went overseas in late February to study the trend of pasture research work. He will spend three months in U.S.A. and four months in Great Britain.

Mr. K. Loftus Hills has just returned to the Division of Plant Industry after a year in the Scientific Liaison Office, Washington.

Dr. J. G. Bald has accepted a position as Associate Professor of Plant Pathology at the University of California, and has returned to Australia before taking up his new duties.

Dr. K. H. L. Key has just returned from Tasmania, where with Mr. P. B. Carne and R. W. Kerr he made a survey of grasshoppers and cockchafers.

Messrs. T. Greaves and J. Calaby, of the Division of Economic Entomology, Canberra, completed a land survey extending from eastern States to Western Australia via the Nullarbor Plains and returning via the coast collecting grasshoppers, termites, flies and jassids from this little known region. Results of considerable importance to entomology were obtained.

Messrs. W. J. Lovett, T. G. Haney and R. Johanson have been appointed to the Tobacco Section, Division of Plant Industry, C.S.I.R.

Mr. Grahame Edgar has been appointed Director of Veterinary Research in charge of the Glenfield Veterinary Research Station in succession to Mr. W. L. Hindmarsh, recently appointed Chief of the Division of Animal Industry, N.S.W. Department of Agriculture.

Mr. H. Bartlett has been appointed Principal Agronomist in the Division of Plant Industry, N.S.W. Department of Agriculture.

Mr. H. Parry Brown has been appointed Organizer of the Agricultural Bureau of N.S.W.

Mr. S. M. Sykes, Fruit Officer, N.S.W. Department of Agriculture, has returned from America where he has been for the past nine months studying the latest developments in quick freezing methods of storing foodstuffs.

Professor G. A. Currie will attend the Empire Universities' Conference at Oxford in July and the Vice-Chancellors' Conference at Bristol. While in London he will confer with the Fairbridge Society, and in August will visit Paris for the UNESCO meeting. En route to U.S.A. as guest of the Carnegie Corporation he will visit the Fairbridge Farm School at Vancouver Island. In U.S.A. he will inspect universities and possibly the T.V.A. scheme, and expects to return to Australia in December.

Mr. H. R. Powell, Superintendent of Horticulture in the W.A. Department of Agriculture, returned in December from Singapore, where he investigated transport of non-ventilated fruit shipments and the marketing of Australian fresh fruit and vegetables.

Mr. W. J. Bettenay, Lecturer in Agriculture at the Muresk Agricultural College, has resigned to join the Department of Commerce, Melbourne, as assistant to the Supervising Officer, Fresh Fruit Export.

Mr. A. F. Bell, Under Secretary of the Queensland Department of Agriculture and Stock, has been appointed chairman of the State Committee of the C.S.I.R.

Mr. J. H. Buzacott, formerly Entomologist in the Bureau of Sugar Experiment Stations, Queensland, has been appointed Senior Plant Breeder in the same organization; Mr. L. G. Vallance becomes Senior Soils Technologist in the Bureau, and Mr. W. J. S. Sloan, previously Agronomist, has left the Bureau to become Senior Agronomist with the Division of Agriculture.

Mr. W. J. Cartmill has been appointed Senior Soils Technologist in the Queensland Department of Agriculture and Stock.

Mr. C. H. P. Defries has been appointed Senior Soils Technologist in the Queensland Department of Agriculture and Stock in succession to Mr. H. K. Lewcock, who has taken a position with a large pineapple firm in South Africa.

Dr. D. A. Herbert, Associate Professor in the Biology Department of the Queensland University, is now Acting Professor of Biology.

Mr. W. C. T. Major, who was formerly a manager of a north Queensland dairy organization, has been appointed Dairy Technologist in the Queensland Department of Agriculture and Stock.

Dr. L. G. Miles, whose work on sorghums and other crops at Biloela is well known, has been appointed Senior Plant Breeder in the Queensland Department of Agriculture and Stock.

Mr. E. J. Breakwell, Senior Lecturer in Agriculture, Sydney University, recently paid a flying visit to Queensland, where, in the company of departmental officers, he saw some of the south-eastern corner of Queensland.

Professor J. A. Prescott, Director of the Waite Agricultural Research Institute, was appointed a member of the Australian Scientific Delegation which visited India early this year. The Delegation left Australia on the 28th December, 1947, and attended meetings at Patna, New Delhi and other centres. Professor Prescott returned to Adelaide late in March.

Mr. R. H. N. Trembath, bacteriologist and biochemist with Sunny South Service Pty. Ltd., has gone to America to investigate the latest technical processes, plant and new products in the dairying industry.

Mr. G. N. Blair, factory manager, Carreras Ltd., cigarette manufacturers, is visiting Great Britain and the United States on a six months' tour.